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& Net Zero

Unlocking Resource Efficiency

Phase 2 Electricals Report

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Introduction

The Department for Energy Security and Net Zero (DESNZ) and the Department for Environment, Food and Rural Affairs (DEFRA) commissioned Eunomia Research and Consulting to undertake a research project exploring the potential benefits from increasing resource efficiency in the UK. This report outlines the findings of this research for the electrical and electronic equipment (EEE) sector.

For the purposes of this report, resource efficiency is defined as any action that achieves a lower level of resource use for a given level of final consumption. This can occur at any stage of the supply chain including production, consumption, and end-of-life. While material substitution may not always meet the definition of resource efficiency set out above, it is in scope of this research where it reduces whole life carbon.

This research was conducted in the second half of 2023, and reports were written in November 2023. As such, this report does not reflect sector developments beyond that point. Technical experts were consulted as part of research activities for this report. The following report reflects our understanding of the available evidence and is accurate to the best of our knowledge; however, if any factual errors are encountered, please contact us at Resource_efficiency@energysecurity.gov.uk.

Methodology

This aim of this research was to achieve four key objectives:

- Identify a comprehensive list of resource efficiency measures for each sector;
- Identify current and anticipated drivers and barriers which are affecting improvements in the identified resource efficiency measures in each sector, and their relative importance;
- Build consensus estimates for the current “level of efficiency” and maximum “level of efficiency” in 2035, for each of the identified resource efficiency measures in each sector; and
- Identify 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 in each sector.

To achieve these research objectives, a mixed-methods methodology was developed. A literature review was conducted for each sector to synthesise evidence from the existing literature relevant to these objectives. In parallel, stakeholder interviews were conducted with industry and academic experts in each sector to test literature findings and fill any outstanding evidence gaps. A summary of findings was then presented and validated at sector-specific facilitated workshops with sector experts.

This project did not aim to identify policy recommendations but rather understand the potential for resource efficiency in the UK. It should be noted that some areas covered as part of the research fall under the responsibility of devolved nations of the UK; however, all reports cover the UK as a whole for completeness.

This project has attempted to identify three level of efficiency estimates for each resource efficiency measure:

- The **current level of efficiency** which is the best estimate for the current level of efficiency of the measure i.e., what is happening in the UK now (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 barriers that could be overcome by 2035 i.e., what is the maximum level that could be achieved; and
- The **business-as-usual (BAU) scenario** which is the level of efficiency that would be expected in the UK by 2035 with the current policy mix and private sector incentives i.e., what would happen if there were no substantial changes in the policy or private sector environment.

These levels of efficiencies have been identified to understand the potential for resource efficiency and do not represent government targets.

To estimate these levels of efficiency, indicators have 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).

For some measures, the current level of efficiency is baselined to 2023. This is not an indication of historic progress, but rather has been done in order to understand the potential for further progress to be made (in the maximum and BAU scenarios) where it was not otherwise possible to quantify a current level of efficiency.

Note, the purpose of the indicators in this research is so estimates on the current, maximum and BAU level of efficiency can be developed on a consistent basis. They are not intended 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.

A high-level overview of the research stages is presented below. A more detailed version of this methodology is presented in the Phase 2 Technical Summary which accompanies this publication.

Literature Review

The literature sources were identified through an online search, and through known sources from DESNZ, DEFRA, the research team, and expert stakeholders.

Once literature sources had been identified they were reviewed by the research team and given an Indicative Applicability Score (IAS) ranging from 1 to 5 which indicated the applicability of the sources to the research objectives of this study. This score was based on five key criteria: geography, date of publication, sector applicability, methodolo-gies used and level of peer review.

After the five criteria of the IAS had been evaluated, the overall IAS score was calculated, ranging from 1 to 5, according to the number of criteria scoring ‘high’ and ‘low.’

A detailed overview of the parameters used to assess high / medium / low scores for each of the five criteria feeding into the IAS calculation and methodology for calculating the score can be found in Appendix A.

The research team drafted a rapid evidence assessment and literature summaries as part of interim reports for each sector which synthesised the best available evidence from the literature for each of the four research objectives. When drafting these summaries, literature sources with a higher IAS score were weighted more than those with a lower IAS score.

Stakeholder interviews

The findings from the literature review were presented to, and tested with, expert stakeholders from each sector through a series of stakeholder interviews. The interviews aimed to capture a range of sector experts from both academia and industry (covering different aspects of the value chain) but it should be noted this is not an exhaustive or representative sample of the sector. The purpose of these interviews was to test the findings of the literature review against stakeholder expertise, and to fill any evidence gaps from the literature.

Facilitated workshops

Following the completion of stakeholder interviews, one half-day facilitated workshop was conducted for each sector. Stakeholders who participated in interviews were given the chance to contribute to supplement and validate findings.

Stakeholders contributed through sticky notes in a shared virtual Mural board, by participating in the verbal discussions and by voting on pre-defined ranges on the levels of efficiency and the top drivers and barriers. They were also given the chance to contribute further information through a post-workshop survey. The stakeholders were asked to signal the level of confidence they had in their votes and were advised to vote for a ‘don’t know’ option if they felt the information fell outside their expertise. It is possible however that some votes were cast in areas where stakeholders may not have had expertise, so caution is advised when interpreting the findings.

Finally, the findings of the literature review and the stakeholder engagement were combined to reach final conclusions against each research objective. For the estimates on the level of efficiency for each measure (Objectives 3 and 4), a five-tier evidence RAG rating was assigned to indicate the level of evidence supporting the proposed figures. Only where the datapoints were supported by literature sources with high IAS and a high degree of consensus amongst experts in the interviews and workshop*,* were the datapoints considered to have a “green” evidence RAG rating. The definitions are as follows:

- **Red:** Limited evidence available from literature review or stakeholders
- **Red-Amber:** Some evidence available from literature review but it is not relevant/out of date, Limited evidence from stakeholders, stakeholders are not experts on this measure

- **Amber:** High quality evidence from either literature or stakeholders
- **Amber-Green:** High quality evidence from literature or stakeholders, evidence from stakeholders is supported by some information in the literature (or vice versa)
- **Green:** High quality evidence from literature supported by stakeholder expertise.

It should be noted that the business-as-usual (BAU) level of efficiency was only informed by the stakeholder engagement, so the maximum evidence RAG rating for the BAU is amber.

Limitations

This report was commissioned by the Government to improve the evidence base on the impact of resource efficiency measures. The methodology is designed to provide robust answers to the research objectives, based on the best available evidence at the time the work was undertaken.

While every effort was made to be comprehensive in the literature review, it is inevitable that some relevant literature may not have been captured. A full list of all the literature reviewed is provided in the annexes of each sector report.

The feedback captured during the interviews and workshops represent the views of a sample of stakeholders from industry, trade associations and academia. Effort was made to ensure that interviews and workshops included a cross-section of stakeholders from each stage of the sectors' supply chain, representing a range of backgrounds and perspectives. It is, however, noted that capacity and scheduling limitations meant that some stakeholders, whose view would have been valuable to the research, were not able to participate. As such, the views expressed by research participants in this report are not representative of the sector as a whole.

A key research objective of this project is to estimate the level of efficiency of resource efficiency measures in 2035. Any future projections are inherently uncertain as they depend on a range of different factors such as technological innovation, consumer behaviour change and the macro-economic environment. The estimates from this research are the best estimates that could be produced, based on the current literature and stakeholder expertise. Evidence RAG ratings have been provided to indicate the level of supporting evidence for each of these estimates.

The report does not seek to make recommendations on the appropriate direction of Government policy or independent industry action. DESNZ and DEFRA will seek to conduct further engagement with stakeholders to inform the next steps for resource efficiency policy within Government, ensuring that any omissions or developments in the evidence reviewed in this report are taken into account.

Sector Introduction

The EEE sector is complex, with a wide range of products consisting of various materials. Technological advances and affordability of EEE, combined with a rising global population and consumerism, have led to a sharp increase in EEE consumption in recent years.[1] For instance, the amount of EEE placed on the European Union (EU) market rose by 63% between 2012 and 2020, from 7.6 million tonnes per annum to 12.4 million tonnes per annum.[2] This increase in EEE consumption has resulted in a large quantity of discarded EEE, otherwise known as electronic waste (e-waste) or waste EEE (WEEE).

Globally, between 2014 and 2019, the amount of WEEE generated increased by 21%, from 44.4 million tonnes per annum to 53.6 million tonnes per annum. By 2030, it is estimated that 74.7 million tonnes of WEEE per annum will be generated globally. Per capita, this equates to 6.4 kg in 2014, 7.3 kg in 2019 and 9.0 kg in 2030. In northern Europe, which consists of the UK, the amount of WEEE produced in 2019 was 22.4 kg per capita – the highest of any global region.[3] Consequently, WEEE has reported as being the fastest growing waste stream in the world.[4] Design for longevity, including durability, repair, refurbishment, and reuse of EEE, as well as the proper collection, recovery and treatment of WEEE, are therefore imperative. Such design and operations will ensure that resources are managed as efficiently as possible as the demand for EEE continues to rise.

The EEE lifecycle is complex, with international supply chains and numerous materials sourced for the various EEE components. These factors present challenges for implementing and monitoring resource efficiency measures. The EEE lifecycle starts with the extraction and refining of raw materials, such as ores and fossil fuels which are transformed into metals and plastics, respectively. In some cases, secondary materials (recycled content) are used. These materials are used for the production and assembly of various EEE components, which are assembled to produce EEE. The EEE is then sold to and used by domestic and commercial consumers. Once the EEE has reached end-of-use, it can be reused, repaired, or remanufactured for continued use by consumers. Alternatively, end-of-use or end-of-life EEE (WEEE) is recycled, incinerated or landfilled.

EEE contains a variety of different materials and chemical elements, including critical raw materials (CRMs, which are rare earth elements such as lithium and tantalum), base metals (such as steel, aluminium and copper), precious metals (such as silver, gold and palladium) and plastics (such as polypropylene (PP) casings and polyvinyl chloride (PVC) wiring insulation). The concentration of some precious metals in WEEE is believed to be greater that the concentration in natural metal ores, meaning the value per tonne of WEEE is greater than the equivalent weight of mined ore.[5] The production of EEE generally requires resource intensive manufacturing, using large amounts of energy and water, whilst often producing large quantities of waste. For certain EEE, negative environmental impacts (such as greenhouse gas emissions and water pollution) are highest at the manufacturing stage of the EEE's lifecycle. For other EEE, the use-phase can incur the highest environmental impacts. For instance, the

[1] Shittu et al. (2022) Prospecting reusable small electrical and electronic equipment (EEE) in distinct anthropogenic spaces. Available at: link
[2] EuroStat (2023) Waste Statistics – Electrical and Electronic Equipment. Available at: link
[3] Forti et al. (2020) The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. Available at: link
[4] Mansuy et al. (2020) Understanding preferences for EEE collection services: A choice-based conjoint analysis. Available at: link
[5] UK Parliament (2020) Electronic waste and the Circular Economy. Available at: link

lifecycle assessment of a Dell laptop suggested that the manufacturing stage contributed to 65% of the laptop's lifecycle carbon emissions, with the majority associated with the production of electronic parts. The use-phase contributed 25%, with the transportation and end-of-life contributing to the remaining 10% of the laptop's lifecycle carbon emissions.[6] Conversely, washing machines[7] and vacuum cleaners,[8] may incur the highest environmental impacts during their use-phase. This can be from the electricity or water used by consumers in order to operate the EEE. For instance, the use-phase of vacuum cleaners in Europe was estimated to contribute to over 80% of a vacuum cleaner's lifecycle carbon emissions, although this varied depending on the country's electricity mix. Specifically, countries using mostly fossil fuels to generate electricity would result in higher use-phase emissions compared with countries using mostly renewable energy to generate electricity.[9] Overall, the combined complexity of the material extraction, manufacturing processes, use-phase requirements and end-of-life treatment options makes EEE a complex sector to implement and monitor resource efficiency measures into.

The design stage of EEE is a key stage at which resource efficiencies may be made. It has been estimated that 80% of a product's environmental impact is determined at the design stage.[10] This places responsibility on EEE designers to consider sustainability during the design process. However, EEE designers may not consider the likely end-of-use scenarios for their products, resulting in EEE not being possible to disassemble for repair, remanufacture or recycling. Additional factors that may contribute to increasing EEE consumption and WEEE generation include:

- Economic obsolescence, whereby the cost of repair or refurbishment is higher than the cost of replacement.[11]
- Technological obsolescence, whereby new software and operating system updates become incompatible with older hardware.[12]
- Perceived obsolescence, whereby consumers perceive technology to be outdated or unfashionable due to technological advances and trends.[13]
- Reduced product quality, whereby the lifespan of the product is shorter than designed or desired.[14]

[6] Dell (2019) Life Cycle Assessment of Dell Latitude 7300 – 25th Anniversary Edition. Available at: link
[7] European Environment Agency (2023) Europe's consumption in a circular economy: the benefits of longer-lasting electronics. Available at: link
[8] Gallego-Schmid et al. (2016) Life cycle environmental impacts of vacuum cleaners and the effects of European regulation. Available at: link
[9] Gallego-Schmid et al. (2016) Life cycle environmental impacts of vacuum cleaners and the effects of European regulation. Available at: link
[10] European Commission (2012) Ecodesign Your Future: How Ecodesign Can Help the Environment by Making Products Smarter. Available at: link
[11] UK Parliament (2020) Electronic waste and the Circular Economy. Available at: link
[12] European Environment Agency (2023) Europe's consumption in a circular economy: the benefits of longer-lasting electronics. Available at: link
[13] Ibid.
[14] Ibid.

- Convenience, whereby the ability to purchase new replacement EEE is considered more convenient, both in time and effort, than repairing the existing non-functional EEE.[15]
- Awareness and understanding, whereby the ability to upgrade, repair or purchase refurbished products is unknown or misunderstood by the consumer.[16]

Current practices and business models for the EEE sector are generally linear, in that they follow the 'take-make-dispose' model of production and consumption. Nevertheless, informal reuse and sharing of EEE is common in the UK, such as donating used EEE to family and friends, and selling used EEE to others through e-commerce platforms such as Gumtree and eBay. Formal reuse of EEE is observed in certain business-to-business (B2B) areas, such as asset management of used IT equipment. For instance, in the UK in 2017, 82,000 tonnes of used domestic EEE was estimated to be sent for reuse, and around 180,000 tonnes of used commercial EEE being sent for reuse.[17] However, circular economy business models such as leasing, product service system arrangements and remanufacture are infrequently utilised. Examples of existing EEE leasing and remanufacture systems are discussed in Section 6.0 Measure 6 – Rental and collaborative consumption models.

The UK has struggled to collect maximum levels of used EEE and WEEE for reuse, repair, remanufacture and recycling. Reasons for this include the delay and mismatch between EEE sales and WEEE arisings, indefinite storage of used EEE by consumers and the disposal of used EEE and WEEE into residual waste bins. Furthermore, given technological advances in recent years with increasingly lightweight EEE, such as televisions and computers, the use of weight-based targets and reporting make it challenging to accurately monitor and evaluate the effectiveness of WEEE collections and recycling rates.

Even where WEEE are recycled through formal channels in the UK, the effectiveness of recovering materials for recycling at Approved Authorised Treatment Facilities (AATFs) can be limited. For instance, some CRMs are not fully recovered, and there are generally low recycling rates of certain other materials such as precious metals and plastics. WEEE plastics are often treated as residual waste due to the likely presence of hazardous elements, such as persistent organic pollutants (POPs), which were often used as a flame retardant for EEE. This is also an issue in other countries, not just the UK. The EEE sector is therefore limited in terms of circularity, meaning there are various resource efficiency opportunities available from the design stage through to the end-of-use and end-of-list stages. However, improving the resource efficiency of EEE requires concerted action by Government, designers, manufacturers, consumers and waste management to tackle the technical, economic and social barriers facing resource efficiency improvements. In tackling these barriers, the EEE sector may be able to improve its resource efficiency.

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[15] Güsser-Fachbach et al. (2023) Repair service convenience in a circular economy: The perspective of customers and repair companies. Journal of Cleaner Production. 415, pp1-11. Available at: link

[16] Ibid.

[17] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link

Sector scope

The EEE in scope of this research include those covered by the UK's Waste Electrical and Electronic Equipment Regulations 2013,[18] driven by the requirements of the WEEE Directive (2012/19/EU).[19] Batteries are out of scope of this research. The scope includes fourteen categories of WEEE (and EEE):[20]

- Large household appliances.
- Small household appliances.
- IT and telecommunications equipment.
- Consumer equipment.
- Lighting equipment.
- Electrical and electronic tools (except large scale stationary industrial tools).
- Toys, leisure and sports equipment.
- Medical devices (except implanted and infected products).
- Monitoring and control equipment.
- Automatic dispensers.
- Display equipment.
- Appliances containing refrigerants.
- Gas discharge lamps and light-emitting diode (LED) light sources.
- PV panels (solar panels).

Resource efficiency measures vary greatly between these categories and the literature available often provides different assessments and findings on the effectiveness of the measures. These categories are referred to in this report where relevant.

Relating to the Office for National Statistics' (ONS) categorisation of products and industries, Table 1 provides key relevant categorisation for the EEE sector. However, it is recognised that various other manufacturing and product categories will be related to the EEE sector in some way – such as the use of EEE and tools to manufacture a product.

Table 1: EEE sector segments based on ONS categorisation.

[18] The Waste Electrical and Electronic Equipment Regulations 2013. Available at: link
[19] European Union (2012) Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2023 of waste electrical and electronic equipment (WEEE). Available at: link
[20] UK Government (2023) Guidance: Electrical and electronic equipment (EEE) covered by the WEEE Regulations. Available at: link.

Product	Industry
P41 - Computer, electronic and optical products	I41 - Manufacture Of Computer, Electronic And Optical Products
P42 - Electrical equipment	I42 - Manufacture Of Electrical Equipment
P43 - Machinery and equipment N.E.C.	I43 - Manufacture Of Machinery And Equipment N.E.C.
P110 - Repair services of computers and personal and household goods	I110 - Repair Of Computers And Personal And Household Goods

As set out in the Defra's 'Maximising Resources, Minimising Waste', the UK Government is working with their counterparts in Scotland, Wales and Northern Ireland to consult on improvements to the current UK-wide WEEE Regulations.[21] The consultation was opened to the public on 28 December 2023, seeking views on reforms to the Waste Electrical and Electronic Equipment Regulations 2013.[22]

Literature review approach

The literature review identified 183 sources that discussed resource efficiency in the EEE sector and other relevant topics. These were identified using a range of search strings relating to resource efficiency, the circular economy and the EEE sector. The search strings are listed in Appendix B. Further sources were identified from sector experts via the interviews and a Call for Evidence sent directly to stakeholders. The full list of sources used are listed in Appendix C.

The 183 sources comprised of:

- 67 website articles;
- 57 academic papers;
- 28 technical studies;
- 21 industry reports; and
- 10 policy documents.

The sources were considered of generally high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of their methodology. The sources had an average IAS of 4.0 (out of 5), with 119

[21] Defra (2023) The waste prevention programme for England: Maximising Resources, Minimising Waste. Available at: link
[22] Defra (2023) Consultation on reforming the producer responsibility system for waste electrical and electronic equipment 2023. Available at: link

sources exhibiting an IAS of 4 or above. There were 61 sources with an IAS of 3 and 3 sources with an IAS of 2. There were 51 sources specific to the UK market and 40 specific to Europe. More detail on the purpose and approach for these literature reviews can be found in the accompanying main report.

Interview approach

A total of eighteen stakeholders were interviewed. These stakeholders represented the EEE value chain. There were five representatives from academia, four from trade associations, three from manufacturers, one from a social enterprise, one from a thinktank, one from a non-governmental organisation (NGO), one from a producer compliance scheme, one from a certification body and one from a consultancy.

Workshop approach

There were seventeen participants in attendance at the workshop. The participants broadly represented the EEE value chain. There were five representatives from four trade associations, three from academia, three from one manufacturer, two from thinktanks, two from social enterprises, one from an NGO and one from a producer compliance scheme. The workshop gathered insightful information from stakeholders, with engaging discussions and voting of levels of efficiency and drivers and barriers associated with each Measure. Findings from the workshop are included in each Measures' section below.

Drivers and barriers

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

List of resource efficiency measures

The list of resource efficiency measures for the EEE sector that were identified through the literature review and stakeholder interviews can be found in Table 2.

Table 2: List of resource efficiency measures for the EEE sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Design	Lightweighting	Lightweighting of electrical and electronic equipment	Average weight decrease of new EEE products placed on the market
2	Design	Recycled content	Use of recycled or recovered materials	% of recycled content by weight of new EEE products placed on the market
3	Design	Material substitution	Use of bio-based plastics	% of bio-based plastic in place of fossil-based plastic
4	Manufacturing and Assembly	Production efficiencies	Increasing material yield and reincorporating waste during manufacture	% of input raw materials that successfully make it in EEE products, considering material losses throughout the supply-chain
5	Sale and use	Lifetime extension	Repair and refurbishment	% of EEE products in use that are repaired or refurbished
6	Sale and use	Collaborative consumption	Rental and collaborative consumption models	% of EEE products in use via circular economy business models and collaborative consumption
7	End-of-life	Remanufacture / reuse	Direct reuse	% of used EEE products that are reused
8	End-of-life	Remanufacture / reuse	Remanufacture	% of EEE that is remanufactured for reuse

#	Lifecycle stage	Strategy	Measure name	Measure indicator
9	End-of-life	Recycling	Recycling of WEEE	% recycling rate of WEEE

1.0 Measure 1 – Lightweighting of electrical and electronic equipment

1.1 Electricals resource efficiency measure

1.1.1 Description

The process of decreasing the mass of a product whilst preserving its overall strength and structural integrity.

Lightweighting is the process of reducing the weight of a product. This can be achieved in the EEE sector by replacing dense materials, such as steel, with a less dense materials, such as plastic. Additionally, different machining and construction techniques can be used to reduce material use for a given product. Either way, reducing the overall weight of a product can improve resource efficiency by using less material and potentially lower the embodied carbon footprint of the product. A lighter product can also require less energy for transportation as a product and as waste.

Through lightweighting, commonly recyclable materials like steel may be replaced by materials that are less commonly recycled. For example, plastics can contain flame retardants consisting of hazardous chemicals, such as POPs, which should not be recycled. Chemical restrictions implemented under EU legislation, REACH, have become more onerous since POPs were introduced.[23]

Notably, product trends and consumer preferences can result in larger, and in some cases heavier, products being manufactured. For example, refrigerators have become larger due to trends towards 'American style' double-doored appliances, whilst other consumer products such as laptops have become thinner and lighter. Televisions have been made thinner, but also larger in screen size, counteracting some of the lightweighting measures.

1.1.2 Measure indicator

The indicator selected was the **average weight decrease of new EEE products placed on the market**. This measures the total amount of products placed on the market and the reduction in weight due to optimising resources or eliminating elements during assembly.

1.1.3 Examples in practice

Lightweighting has been achieved for many EEE. Dense materials, such as steel, have commonly been replaced with plastics, or in some cases by ceramics in a thermal management solution.[24] Products can also be manufactured in a way that uses less material.

[23] Priority Waste (2023) Persistent Organic Pollutants (POPs) in Plastics: Impact on WEEE Recycling. Available at: link
[24] BOYD (2022) What is Lightweighting and Why is it Important? Available at: link

For example, rather than using solid material, hollowed structures can be used which retain their structural integrity whilst reducing material use and weight. 3D printing or additive manufacture can also be employed to reduce overall material wastage, as opposed to machining from a solid metal billet, for example. Optimising the design can also involve miniaturisation or the consolidation of components in order to achieve a lighter product. Another example of lightweighting is the increased functionality of products. Smartphones and tablets, for instance, can replace the requirements for a separate camera, music player and calculator, whilst also serving as a telephone and messaging device.

1.2 Available sources

1.2.1 Literature review

The literature review identified nineteen sources that discussed lightweighting as a resource efficiency measure. These comprise:

- Fourteen website articles;
- Two academic papers;
- One industry report;
- One technical study; and
- One policy document.

Due to the high number of sources, they have been listed in Appendix C rather than as footnotes.

The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.7 (out of 5) with nine sources exhibiting an IAS of 4 or above. Three sources were UK-specific, and eighteen of the sources were from the last ten years.

1.2.2 Interviews

Nine of the stakeholders interviewed commented on lightweighting of EEE as a resource efficiency measure, discussing levels of efficiency and drivers and barriers for the different applications, depending on their area of expertise. There were a number of drivers mentioned, including carbon and cost savings, technological advancements and improved consumer ease of use. EU legislation was mentioned by one stakeholder as a driver, but another stakeholder said the variety of products makes legislation challenging. Other barriers mentioned included conflicts with increasing recyclability and durability, as well as noting that a lot of EEE manufacturing occurs outside of the UK, and so there is often minimal control over the manufacturing stage.

When discussing levels of efficiency, stakeholders agreed that EEE lightweighting was being achieved to a certain extent, mostly through material change from steel to plastics. However, in some cases, the material change does not reduce the overall product weight. One stakeholder stated that whilst there has been some downsizing of portable electronics, the overall percentage weight of metal is consistent at a level of around 40%. Conversely, another stakeholder said that there could be weight savings of up to 30%, based on a case study on steel and aluminium products. When discussing the business-as-usual level of efficiency, there was a consensus that there are some EEE which are getting smaller and lighter and some that are not, so it was difficult to make an accurate estimate. Additionally, some EEE might be getting lighter naturally through product improvement, without a specific focus on trying to make EEE lighter.

1.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 1. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academics, industry bodies and manufacturers. However, manufacturers for consumer electronics were absent. There was a high level of uncertainty for levels of efficiency on this Measure due to unknowns on how future consumer, market and technology trends will influence EEE lightweighting. There were no votes on the current level of efficiency. There were eleven votes for the business-as-usual level of efficiency, with the majority voting “Don’t Know”. The maximum level of efficiency received eleven votes, similarly with many of the stating “Don’t Know”.

There was a lot of discussion around the range of EEE products and how it is challenging to determine the potential for lightweighting of such varied products – from small EEE, such as mobile phones and laptops, to larger household appliances, such as fridges and washing machines. Some EEE, like televisions, are complicated in that they have increased their screen size but have become slimmer and lighter due largely to LED technology. Cameras are reducing in numbers as smartphones take over their function. Items like vacuum cleaners have reduced in weight by switching from metal to plastic, and then from corded to cordless compact models. Fridges have increased in size and weight, but new appliances such as ‘air fryers’ have appeared and become more popular – adding to the number and weight of EEE placed on the market. It was also noted that lightweighting of products can lead to issues in other areas, such as making products less durable and less recyclable.

The level of engagement in the workshop was as follows:

- Thirteen stakeholders across industry and academia were active on the mural board voting for levels of efficiency, drivers and/or barriers.
- Seven stakeholders actively contributed to verbal discussion, although there was no further commentary on the Teams chat.

1.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and the EEE sector workshop.

1.3.1 Drivers

There was consensus that this Measure will, in the future, be driven by consumer demand and market forces rather than technological advances and material changes per se (much of which has already been achieved).

Lightweighting can help to deliver greater material efficiency and reduce product costs. However, finding the optimal balance between weight, functionality, durability and recyclability is key. Table 3 below shows the main drivers for Measure 1. The most significant drivers are shown in bold, as voted for by stakeholders in the workshop.

Table 3: Drivers for EEE Measure 1

Description	PESTLE	COM-B
Cost savings through using less material.[25 26 27]	**Economic**	**Motivation – reflective**
Easier and cheaper to transport as they are lighter.[28 29]	**Technological**	**Motivation – reflective**
Legislation in the EU.[30]	**Legal**	**Motivation – automatic**
Lower environmental impact through less raw materials and resources used.[31]	**Environmental**	**Capability – physical**
Better ergonomics and ease of use for users.[32 33]	Technological	Motivation – automatic
Gives the consumer the option to make a more sustainably conscious choice.[34]	Environmental	Motivation – automatic
The existence of guidance and best practice standards to utilise less material.[35]	Legal	Motivation – automatic

[25] Crawford, M. (2022) 7 benefits of lightweighting. Available at: link
[26] BOYD (2022) What is Lightweighting and Why is it Important? Available at: link
[27] Stakeholder interviews
[28] nTop (2022) 8 benefits of lightweighting in manufacturing and engineering. Available at: link
[29] Global Electronic Services Inc. (2023) What Are the Benefits and Challenges of Lightweight Manufacturing? Available at: link
[30] Stakeholder interviews
[31] Stakeholder interviews
[32] nTop (2022) 8 benefits of lightweighting in manufacturing and engineering. Available at: link
[33] Stakeholder interviews
[34] Stakeholder interviews
[35] Stakeholder interviews

Description	PESTLE	COM-B
Companies can market Green Credentials.	Social	Opportunity – social

Cost savings and improved environmental impact through using less material

The use of lightweight materials can reduce the overall weight of material needed for EEE production, therefore resulting in a direct cost saving. The lightweight materials may also be more efficiently utilised. Lightweighting often removes elements or components from a product in order to achieve a lighter item. This, therefore, requires fewer raw materials and resources in the manufacturing of the product, also resulting in lower carbon emissions. During the workshop, five of the twenty-seven votes for top three drivers were for cost savings. There were a further six votes for lower environmental impact from fewer resources used.

Transportation

Lighter products have lower associated fuel costs than their heavier counterparts. In the workshop, three of the twenty-seven votes for top three drivers were for this driver.

Legislation in the EU

Future legislation may have the impact of increasing the trend towards lighter products, such as legislation incentivising or mandating reduced material use and associated weight of products placed on the market – such as Extended Producer Responsibility (EPR) and eco-design. In the workshop, five of the twenty-seven votes for the top three drivers were for this driver.

1.3.2 Barriers

Overall, while the benefits are substantial, lightweighting EEE requires overcoming design, manufacturing, supply chain and marketing challenges (lighter products are often seen by consumers as being of lower quality). Gradual and systematic efforts focused on optimal trade-offs are key.

Table 4 below shows the main barriers for Measure 1. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 4: Barriers for EEE Measure 1

Description	PESTLE	COM-B
Lower durability.[36]	**Technological**	**Capability – psychological**

[36] Stakeholder interviews

Description	PESTLE	COM-B
Recyclability of some of the lighter products (i.e., if steel has been replaced with plastic which contain POPs).[37]	**Technological**	**Motivation – automatic**
Design for disassembly.[38]	**Technological**	**Capability – physical**
Safety concerns.[39] [40]	Social	Motivation – automatic
Consumer perception of lighter weight being lower quality.	Social	Motivation – automatic
Reduced product lifecycle, pace of innovation may cause previous lightweight materials to become obsolete more quickly.	Technological	Capability – physical
Legislation is challenging due to range of product categories.[41]	Legal	Motivation – automatic

Durability

Lighter materials, such as plastic, are often lighter, cheaper, but less durable than their metal equivalents.[42] [43] With an increase in steel being replaced with plastic to make EEE lighter, this can make EEE less durable. It should also be noted that any move to circular economy business models (e.g., multiple reuse cycles) may require more durable EEE. This could mean that EEE would need to be made from stronger and potentially heavier materials, using more robust designs.

In the workshop, there were four votes for durability being amongst the top three barriers for Measure 1.

Recyclability

The lightweight materials used in EEE can often be non-recyclable and therefore effect the end-of-life treatment of WEEE. Many household EEE, such as toasters, have replaced metal

[37] Priority Waste (2023) Persistent Organic Pollutants (POPs) in Plastics: Impact on WEEE Recycling. Available at: link
[38] Stakeholder Interview
[39] Global Electronic Services Inc. (2023) What Are the Benefits and Challenges of Lightweight Manufacturing? Available at: link
[40] Stakeholder interviews
[41] Stakeholder interviews
[42] AccuBrass (2021) Metal vs. Plastic: Which Is Better for Manufacturing. Available at: link
[43] Kerns, J. (2017) Machine Design – Replacing Metal with Plastic. Available at: link

with plastic. Because of the nature of the product, the plastic must be flame retardant. POPs were added to the plastic to make it flame retardant, which prevents it from being recycled. The end-of-life option of POP-containing materials is therefore disposal. This restricts its overall environmental performance. In the workshop, there were three votes for recyclability being amongst the top three barriers for Measure 1.

Design for disassembly

The ability to disassemble EEE for repair, refurbishment or recycling is often sacrificed when lightweighting a product. Bonding or welding of materials can help to reduce weight, maintain structural integrity and simplify manufacture. This can reduce the cost of the product, but prevents disassembly without making the product unusable. In the workshop, there were two votes for design for disassembly being amongst the top three barriers for Measure 1.

1.4 Levels of efficiency

Table 5: Levels of efficiency for EEE Measure 1

Indicator: Average weight decrease of new EEE products placed on the market compared to 2023 levels			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	0%	30 – 40%	1 – 10%
Evidence RAG	N/A	Red	Red

1.4.1 Current level of efficiency

There has been a trend towards lighter and thinner consumer EEE, such as laptops and mobile phones, and advancements in materials and components has allowed many devices to achieve this. There has also been a move to wireless options, such as headphones and speakers, which has allowed items to become lighter due to the absence of components and materials. Many home appliances like microwaves and toasters have decreased in weight through the replacement of metals with plastics. However, for larger appliances, such as refrigerators and washing machines, the change in weight has not been as clear or substantial. Some appliances have added features which require more internal components and thus an increase in weight. Additionally, some items like televisions are increasing in weight due to larger screen sizes and higher resolutions which require more internal components and casing materials. For instance, in 2012, the average LCD television screen in the US was 38 inches; whilst in 2022 the average LCD/LED television screen size was 50 inches.[44] [45]

When looking at laptops, in 2012 a 15-inch laptop weighed around 2.5-3 kg,[46] whereas in 2022 a 15-inch laptop weighed around 1.8-2.2 kg, which is a 30% reduction.[47] The reductions in laptop weight have been due to a transition to lighter hard drives, improvements in battery size and life and the use of lighter materials, among others.[48]

Some smartphones, such as Apple's iPhone have increased in weight, depending on the model. The iPhone 14 Pro Max weighs 240g compared to the iPhone 4 which weighed 137g.[49] [50] This was due to an increased screen size, battery capacity and material use.

Stakeholders during interviews agreed that EEE lightweighting had been observed, particularly through the replacement of metals with plastics, but could not provide any quantitative data. Based on this and the mix of some items decreased in weight and other increased in weight, a current value of 0% has been given, and will act as the baseline. Since the current level of efficiency has been set at 0%, there were no comments or votes by stakeholders for the current level of efficiency in the workshops.

1.4.2 Maximum level of efficiency in 2035

There is still potential for further lightweighting for EEE. There is also a trend towards miniaturisation of many EEE, which can decrease the weight. The advancements of 3D printing could enable reduced wastage of materials, which will make the manufacturing process more efficient (such as additive manufacture rather than removal of materials from a moulded or cast item, for example). However, the potential use of 3D printing must not be overstated at this stage. Although a 3D printed counterpart may have the same shape and appearance as the original piece, the materials used and structural integrity of the piece still need to match original design specification in order to guarantee safety and appropriate performance.[51]

Unfortunately, there was no data found to indicate how much lighter items could be. However, one stakeholder during interviews indicated that 30% weight savings in metal could be achieved for large household appliances. Other stakeholders indicated that a 60% reduction could be stated as the maximum level of efficiency. There will be a limit on many components or elements where they can no longer be made smaller or lighter without affecting their functionality. Based on the information from the interviews and how items have reduced in weight over the past ten years, it would be reasonable to estimate that the maximum level of efficiency in 2035 would be around 30-40%.

[44] Statista (2023) Average size of LCD TV screens in the United States from 1997 to 2022. Available at: link
[45] Wired (2022) Why TV screens are going extra large. Available at: link
[46] The Verge (2012) Samsung Series 9 review (13-inch, mid-2012). Available at: link
[47] Kenpachi, Z. (2023) How Much Does a Laptop weigh? Updated 2023. Available at: link
[48] Kanchwala, H. (2022) Why Are Laptops Getting Lighter and Slimmer? Available at: link
[49] Apple (2023) iPhone 14 Pro Max – Technical Specifications. Available at: link
[50] Apple (2014) iPhone 4 – Technical Specifications. Available at: link
[51] Stakeholder interviews

In the workshop, eleven of the seventeen stakeholders voted on the maximum level of efficiency in 2035. There was a good coverage of stakeholders from academics, trade associations and NGOs. Out of the eleven stakeholders, there were six votes for “Don’t Know” and two votes for “Other”, with no alternative ranges being put forward. There were three votes for 30-40%, two with low confidence and one with medium confidence. There was uncertainty expressed around where consumer trends and consumer behaviour could lead, and therefore uncertainty on this level of efficiency. Due to these votes, the RAG rating for this level of efficiency has been changed from amber to red. Without further quantified estimates, the range of 30-40% for the maximum level of efficiency in 2035 has remained. Whilst this does seem high and possibly unrealistic, none of the input from stakeholders suggested any other levels of efficiency, and as such the level has remained but with a red RAG evidence rating.

1.4.3 Business-as-usual in 2035

It is unclear what the level of efficiency will be in a business-as-usual scenario in 2035. According to the Environment Agency (EA), the tonnage of household EEE placed on the market in the past ten years has increased by 28%.[52] Whilst this is based on tonnages and not number of items placed on the market, it may indicate that not all items have reduced in weight. The total weight of large and small household appliances has increased in weight by 25% and 28%, respectively; whilst IT and telecoms equipment and consumer equipment have reduced by 10% and 36%, respectively.[53] Given that trends differ between product groups (e.g., consumer desire for larger televisions and fridges, but lighter laptops) it is difficult to say what impact lightweighting will have on EEE. Similarly, stakeholders interviewed agreed that although some EEE are becoming smaller, other product categories are increasing in size and weight. For those categories, where there is potential for lightweighting, stakeholders suggested that the business-as-usual level of efficiency could reach the maximum, which is 30-40%. However, based on initial findings and interviews, a level of efficiency of 1-10% was estimated.

In the workshop, seven of the seventeen stakeholders voted on the business-as-usual level of efficiency in 2035. There was one vote for 0% with high confidence, and three votes for a range of 1-10%, two of which had a confidence level of medium confidence and one vote not providing a confidence level. There were seven votes for “Don’t Know”. The commentary around this was that the level of efficiency is hard to assess and will vary greatly depending on the product groups and how their business model supports repair, remanufacturing and refurbishment, as lightweighting can be seen as a barrier to these. Similar to the maximum level of efficiency, there were comments on consumer trends and uncertainties regarding future technology. As such, the business-as-usual level of efficiency has remained 1-10%, with a red RAG evidence rating.

[52] UK Government (2023) Electrical and electronic equipment (EEE): producer responsibilities. Available at: link
[53] UK Government (2023) Electrical and electronic equipment (EEE): producer responsibilities. Available at: link

2.0 Measure 2 – Use of recycled or recovered materials

2.1 Electricals resource efficiency measure

2.1.1 Description

The use of recycled materials or recovered materials in the design and manufacture of EEE.

High levels of recycled content are found in steel and aluminium, and these metals are widely used in EEE.[54] Recycled plastics are more problematic in that the formulations used in EEE are often very specific and the performance and quality requirements can be difficult to achieve using high levels of recycled content.

2.1.2 Measure indicator

The indicator for this measure is the **percentage of recycled content by weight of new EEE products placed on the market.** The use of recycled content results in lower overall resource use, and the associated carbon and other impacts of using virgin materials.

2.1.3 Examples in practice

There are numerous examples of post-consumer recycled (PCR) as well as pre-consumer/post-industrial recycled (PIR) plastics being used to replace the use of virgin plastics. Steel and aluminium have consistently high levels of recycled content (often 40% to 50%).[55] [56]

'Green' products in a manufacturers range may have high levels of PCR (over 70% in some cases),[57] but overall PCR use remains low. There is, however, significant effort now being made by various companies to use recycled plastic, such as SMEG, DeLonghi, Beko, Harman and Numatic.[58] [59] [60] Several companies look at ease of substitution for materials using the "PolyCE 4 step" principals.[61]

The company Electrolux has set a target to replace virgin plastic with recycled plastic and increase the amount of recycled plastic in products to 20,000 tonnes per year. Their target is to increase the percentage of recycled plastic by 50% on their current level (13%). Electrolux has calculated that carbon emissions resulting from the production of virgin plastic for their

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54 Novelis Recycling UK (2023) Why Recycle Aluminium? Available at: link
55 Stakeholder interviews
56 SCS Standards (2023) Supplemental Criteria for Electrical and Electronic Equipment. Available at: link
57 SCS Standards (2023) Supplemental Criteria for Electrical and Electronic Equipment. Available at: link
58 SMEG (2023) Tritan Renew. Available at: link
59 Numatic (2023) ERP180 – Powerful, Sustainable Cleaning. Available at: link
60 Stakeholder interviews
61 PolyCE (2021) Design for Recycling: Practical Guidelines for Designers. Guidelines for Electrical and Electronic Equipment. Available at: link

products are equivalent to the carbon emissions from operations and transport activities combined, so the positive environmental impact from using recycled plastic is significant.[62]

Sony have also developed SORPLAS, which is a recycled flame-retardant plastic. SORPLAS is made from used water bottles and waste optical discs collected from factories and markets, and a proprietary flame retardant that avoids the use of POPs. It is used in a variety of Sony and other brand products such as cameras and televisions.[63] According to Sony, sulphur-based flame retardants do not reduce the quality of plastics and can be recycled several times without the loss of quality.[64]

2.2 Available sources

2.2.1 Literature review

The literature review identified twenty-eight sources that discussed recycled content as a resource efficiency measure. These comprise:

- Ten website articles;
- Six academic papers;
- Six technical studies;
- Four industry reports; and
- Two policy documents.

Due to the high number of sources, they have been listed in Appendix C rather than as footnotes. The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.7 (out of 5), with twelve sources exhibiting an IAS of 4 or above. Three sources were UK-specific, and twenty-six of the sources were from the last ten years.

2.2.2 Interviews

Nine of the stakeholders interviewed commented on use of recycled or recovered materials as a resource efficiency measure, discussing levels of efficiency and drivers and barriers for the different applications, depending on their area of expertise. The main drivers given were cost and carbon savings as well as design guidelines and commitments. There were a number of barriers mentioned by the stakeholders. There were concerns over the plastics in EEE containing POPs, which make them flame retardant but also making them non-recyclable. Material supply issues was also mentioned as a barrier, including conflicts with other sectors. Lack of bans and taxes around the use of recycled content was also mentioned as a barrier as well as limited WEEE collection infrastructure.

[62] Electrolux (2021) Offer circular products and business solutions. Available at: link
[63] Sony (2023) SORPLUS recycled plastic. Available at: link
[64] Raudaskoski et al. (2019) Designing plastics circulation – electrical and electronic products. Available at: link

In terms of levels of efficiency, in current levels there was a mix of figures. One stakeholder provided a range of between 0% and 85% of plastic being recycled plastics and stated that the use of recycled metals was high. Another stakeholder said there were certain EEE that might have a high recycled content, but overall the use of recycled material remained low. When looking at maximum levels, recycled metal use could go as high as 100% and plastics to 85% according to one stakeholder. They did state this would be product specific. One stakeholder said that when looking at business as usual, manufacturers are not going to increase beyond 30% recycled content as this regarded as the industry target. Companies will want to appeal to the consumer, but many are unlikely to go beyond what is targeted.

2.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 2 with a high level of engagement. The stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academics, social enterprises, a trade body, a thinktank, a producer compliance scheme and an NGO. There was a mixture of high, medium and low confidence for the levels of efficiency. There were eight votes for the current level of efficiency, fourteen votes for the maximum level of efficiency and thirteen votes for the business-as-usual level of efficiency. There was a low or medium confidence on the levels of efficiency, however there were no additional quantified levels provided. There were concerns regarding plastic that contained POPs, and how this would affect the recyclability. Additionally, there were discussions around export and trade of plastic, with discussions about the bans on exports.

The level of engagement in the workshop was as follows:

- Twelve stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Five stakeholders actively contributed to verbal discussion, with one stakeholder contributing on the Teams chat.

2.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

2.3.1 Drivers

Table 6 below shows the main drivers for Measure 2. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 6: Drivers for EEE Measure 2

Description	PESTLE	COM-B
Cost savings.[65]	**Economic**	**Opportunity – psychological**
Lower energy requirements.[66] [67]	**Economic**	**Capability – physical**
Trends towards mandated recycled content.[68]	**Political**	**Opportunity – social**
Trend towards manufacturers getting certifications related to recycled content or corporate commitments.[69]	Social	Opportunity – social
Consumer demand of more eco products.[70]	Social	Motivation – automatic
The necessity to reach resource security, particularly for CRMs, in the UK.[71]	Political	Motivation – automatic
Policy requirements in the EU, such as The Ecodesign Directive for Sustainable Products (ESPR) and eco-modulation.[72]	Legal	Motivation – automatic

Cost savings

With use of recycled content, less primary raw material is used, in some cases presenting cost savings to manufacturers. It is worth noting that the disparity in costs between virgin plastic and recycled plastic is contingent on factors like the balance of supply and demand for recycled plastic, the influence of energy prices on recycling processes and the market prices of fossil-based resources like oil and gas, which impact the cost of virgin plastic.[73]

In the automotive industry, recycled plastic content (which involves similar polymers to EEE) can be 10% less expensive than virgin plastic.[74] A specific case study exemplifies this cost

[65] Stakeholder interviews
[66] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[67] Stakeholder interviews
[68] Stakeholder interviews
[69] Stakeholder interviews
[70] On the Edge (2021) Recycled Content in Packaging: What you Need to Know. Available at: link
[71] Stakeholder interviews
[72] Stakeholder interviews
[73] Ambrose, J. (2019) War on plastic waste faces setback as cost of recycled material soars. Available at: link.
[74] Oakdene Hollins (2021) Driving change: A circular economy for automotive plastic. Available at: link

advantage, revealing a noteworthy 40% savings achieved by utilising a combination of post-consumer and post-industrial recycled plastic content for interior trim.[75]

Another example comes from a comprehensive study that projected the global average cost per tonne for virgin versus recycled plastic content across six polymers from 2019 to 2040. The findings indicated that, irrespective of the scenarios considered (including a business-as-usual scenario), recycled plastic content was anticipated to cost less than virgin plastic content by the year 2040.[76]

As such costs can been considered a driver as well as a barrier which is discussed in section 2.3.2 Barriers. In the workshop, three of the thirteen votes for the top three drivers were for cost savings.

Lower energy requirements, better environmental performance

The energy usage and emissions related to recycling plastic are lower than the emissions related to producing new virgin plastic material from fossil fuel feedstocks. One study found that when substituting 30% of virgin polycarbonate (PC) with recycled PC, it reduced the environmental impacts of plastic production by 23%.[77] An increase in recycling of plastics will also reduce emissions compared with the disposal of plastic as waste, particularly where incineration is used. The energy and carbon savings in making steel from scrap metal (Electric Arc Furnace) and aluminium from used beverage cans, for instance, is even greater, often being quoted as over 90% energy saving for aluminium when compared to manufacture from mined bauxite.[78] [79]

In the workshop, two of the thirteen votes for the top three drivers were for lower energy requirements.

Mandated recycled content targets

There is a general trend towards mandating and incentivising the use of recycled content in products. For example, the UK Plastic Packaging Tax imposes taxes on any plastic packaging that does not contain at least 30% recycled plastic content.[80] Stakeholders remarked that expanding this to cover other plastic products would encourage the use of recycled plastics further.[81] There is evidence of financial obligations for EEE producers being discussed in Parliament, most recently in February 2021,[82] and more recently in regard to potential changes

[75] Van Der Vegt et al. (2022) Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective. Available at: link
[76] Google and AFARA (2022) Closing the Plastics Circularity Gap: Full Report. Available at: link
[77] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[78] Alupro, Environmental Benefits. Available at: link
[79] Recycle-More, Steel. Available at: link
[80] UK Government (2021) Guidance: Plastic Packaging Tax: Steps to Take. Available at: link
[81] Stakeholder interviews
[82] UK Parliament (2021) Electronic Waste and the Circular Economy: Government Response to the Committee's First Report. Available at: link

to the UK WEEE Regulations. In the workshop, three of the thirteen votes for the top three drivers were for mandated recycled content targets.

2.3.2 Barriers

Table 7 below shows the main barriers for Measure 2. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 7: Barriers for EEE Measure 2

Description	PESTLE	COM-B
Lack of supply of high-quality and in some cases food grade materials.[83] [84] [85]	**Technological**	**Capability – physical**
Technical performance – e.g., strength and finishes of the final product.	**Technological**	**Capability – physical**
Costs of certain virgin materials can be cheaper than secondary materials.[86]	**Economic**	**Opportunity – psychological**
POPs preventing closed loop recycling of flame-retardant materials.[87]	Technological	Capability – physical
Lack of financial incentives – e.g., reduced EPR fees based on the percentage of recycled content, other tax breaks.[88]	Economic	Opportunity – psychological
Lack of expansion of the Plastic Packaging Tax to cover other products.[89]	Legal	Motivation – automatic
Weak collection infrastructure.[90]	Technological	Capability – physical
Use of glue as a joining method for plastics prevents them being separated for recycling.[91]	Technological	Capability – physical

[83] OECD (2022) Plastic pollution is growing relentlessly as waste management and recycling fall short. Available at: link
[84] Eunomia Research & Consulting (2023) Defining Recyclate Quality Target Specification to Improve Plastic Packaging Circularity. Available at: link
[85] Stakeholder interviews
[86] Stakeholder interviews
[87] Stakeholder interviews
[88] Stakeholder interviews
[89] Stakeholder interviews
[90] Stakeholder interviews
[91] Stakeholder interviews

Lack of supply of reprocesses/ recycled materials.

In order for an increase in the use of recycled plastic in EEE, there needs to be a sufficient supply of recycled materials on the market. It is believed that, globally, only around 9% of plastic waste is recycled, whilst 22% is mismanaged.[92] There will naturally be reservations from manufacturers on setting recycled content targets and committing to recycled content when there are concerns over feedstock availability.

Technical Performance

Recycled plastic content may not provide the required performance, for example strength or aesthetics, that would be available from virgin plastics. Recycled plastic can, however, be more widely used in internal components and assemblies. In the workshop, two of the twelve votes for the top three barrier were for technical performance.

Increased Costs

In Europe, the surging demand for recycled plastic in packaging has led to an escalation in recycled plastic prices, surpassing the cost of virgin plastic in certain cases. Additionally, the cost differential is affected by the polymer type and the requisite quality standards for recycled plastic, necessitating specific processing and treatments, particularly for applications like food-contact packaging or those with specific aesthetic requirements.[93]

Energy costs play a pivotal role in determining recycled plastic expenses. Recent increases in energy prices, predominantly linked to the conflict in Ukraine, have significantly impacted European plastic recycling facilities. Prior to the energy price surge in 2022, energy constituted approximately 15-20% of the operating costs for these facilities, which primarily covered energy, labour, and maintenance. However, the 2022 surge elevated energy costs to around 70% of operating expenses, leading some facilities to halt operations due to the financial strain.[94]

2.4 Levels of efficiency

Table 8: Levels of efficiency for EEE Measure 2

Indicator: % of recycled content by weight of new EEE products placed on the market			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035

[92] OECD (2022) Plastic pollution is growing relentlessly as waste management and recycling fall short. Available at: link
[93] Evans, J. (2022) Recycled plastic prices double as drinks makers battle for supplies. Available at: link
[94] Vaclavova, B. (2022) High energy costs put plastic recycling ‘at risk’. Available at: link

Value of recycled plastic content	1%	70%	50%
Evidence RAG	Amber	Amber	Red
Value of recycled metal content	30%	90%	80%
Evidence RAG	Green	Amber	Amber

2.4.1 Current level of efficiency

According to a PolyCE video, only 1% of consumer EEE has recycled content,[95] a figure which concurs with data obtained when working on the EU Plastics Strategy in 2017. The figure may be higher, but the consensus is that the levels are very low. Whilst there are certain manufacturers who have increased the amount of recycled plastic in products, it is predominantly in internal parts. Overall, the use of recycled plastics compared to virgin fossil-fuel based plastics is still relatively low, and the use of recycled plastic does not appear to be homogenous across the whole sector.[96]

Apple have stated that, on average, 50% of the plastic used in their products is recycled plastic, with one element being made up of 90% recycled plastic.[97] Sony's recycled plastic SORPLAS is a high performing plastic even when using up to 99% recycled content.[98] Electrolux inner (non-food contact) liners in refrigerators are made with 70% recycled plastic.[99]

Some stakeholders during interviews indicated that they currently use 20% to 30% plastic in some vacuum cleaners and other machines (mainly B2B appliances) with an average of 18%. Although they confirmed that policy is to aim to increase the amount of recycled content where possible, they confirmed that material quality remains an issue. As such, the level of efficiency for recycled plastic was initially estimated at 1%, with green RAG evidence rating. When looking at recycled metal content there was consensus that the levels being used were already quite high. Additionally in certain Apple products, 100% of aluminium and gold used were recycled metals.[100] This figure is only relevant for certain products and elements of those products, and while it is unclear what the use of recycled metal is across the industry, steel and aluminium often contain around 40% recycled content.[101] In this, case a more conservative level of efficiency for recycled metal content of 30% was initially estimated.

[95] PolyCE (2020) PolyCE Project: A Social Experiment. Youtube video. Available at: link
[96] PolyCE (2021) Design for Recycling: Practical Guidelines for Designers. Guidelines for Electrical and Electronic Equipment Available at: link
[97] Apple (2021) Environmental Progress Report. Available at: link
[98] Sony (2023) SORPLUS recycled plastic. Available at: link
[99] Electrolux Group (2023) Circularity wins: Our recycled plastic fridge inner liner scoops top award. Available at: link
[100] Apple (2021) Environmental Progress Report. Available at: link
[101] EuRIC AISBL (N.D.) Metal Recycling Fact Sheet. Available at: link

In the workshop, four out of the seventeen stakeholders voted on the current level of efficiency for plastic, however all four voted for “Don’t Know”. They stated that it is difficult to know this without assessing at a product level. When looking at metal, there were also four votes for the current level of efficiency, two voted “Don’t Know” with a high confidence level, one voted 30% with a high confidence level and one voted less than 30% but there was no confidence level attached. There was no alternative level of efficiency provided, and so the level of efficiency and RAG evidence ratings have remained the same based on the workshops – i.e., 1% for plastic and 30% for metal.

2.4.2 Maximum level of efficiency in 2035

There is the potential for the majority of internal plastic components to be made of recycled plastics, however due to concerns on the finish of recycled plastic it is unlikely that a consumer product will be made up of 100% recycled plastic. The global post-consumer recycled plastics in consumer EEE market size was estimated at US$12.92 million in 2022 and is expected to grow at a compound annual growth rate of 10.5% from 2023 to 2033. The market is poised for growth due to the increasing adoption of post-consumer recycled plastic resins in the production of consumer EEE.[102]

Stakeholders agreed that the content of recycled plastics in EEE could be higher than 85%, while in metals it could be almost 100% (given that recycled content does not affect the performance of metals). Another stakeholder indicated that there is unlikely to be sufficient metals in circulation to reach 100% recycled content, such as gold. Other stakeholders indicated that it would likely be around 50% across the sector when concerning plastics. A mid value between 85% and 50% was initially estimated for the maximum level of efficiency. This will likely be based on performance requirements from product to product.

In the workshop, seven of the seventeen stakeholders voted on the maximum level of efficiency in metals. There were three votes for 90%, one with low confidence, one with medium confidence and one without a confidence rating. The remaining votes were for “Don’t Know”. There were also seven votes for the maximum level for plastics, two stakeholders voted for 70%, one with low confidence, and one with high confidence. The remaining votes were for “Don’t Know”. There was no alternative level of efficiency provided, and so the level of efficiency and RAG evidence ratings have remained the same based on the workshops – i.e., 70% for plastic and 90% for metal. There were discussions around recycled materials behave differently to virgin materials which could prevent an increase in use of recycled material, however it was noted that there is a clear need to recycle and that there is a high demand for recycled material, particularly food grade plastics from manufacturers.

[102] Grand View Research (2023) Post-consumer Recycled Plastics in Consumer Electronics Market Size, Share & Trends Analysis Report by Source (Non-bottle Rigid, Bottles), By Type, By Application (LCD Panels, Wearables), By Region, And Segment Forecasts, 2023 – 2033. Available at: link

2.4.3 Business-as-usual in 2035

One large appliance manufacturer noted that they have a 30% PCR target across the range by 2027, however the cost of including recycled content is a concern.[103] Some products will have more recycled content, whereas others will have less, due to performance, safety or food contact constraints. Similarly, companies such as Apple, Beko, Dell and Samsung have sustainability commitments to increase the use of recycled plastics in their products. Stakeholders in interviews agreed that company commitments and a desire to become more ‘environmentally friendly’, particularly to appeal to the consumer, will drive an increase in the business-as-usual level of efficiency, with recycled plastic content having the potential to reach 50%. While an aggregate percentage across the entire EEE industry is difficult to estimate, it appears that there is clear momentum from both brands and regulators to increase the usage of recycled plastics. A value of 50% for plastic recycled content was initially estimated.

During the workshop, six of the seventeen stakeholders voted on the business-as-usual level of efficiency for recycled plastics. There were four votes for a level of 50%, three of which had low confidence and one which did not have a confidence rating. There was a vote for less than 50% with a vote of high confidence. There was one vote for “Don’t Know”. The RAG evidence rating for the business-as-usual level of efficiency was red and has remained unchanged. The commentary around this was that this needs to be considered at a product level and POPs legislation needs to be considered. Additionally, there is a demand from other sectors for recycled plastics, and the use of recycled plastics can have an effect on the durability of products.

The use of recycled metal appears to be on the increase when speaking with the stakeholders, and there are fewer barriers compared to the use of recycled plastic. When looking at metal, seven of the stakeholders voted for the level of efficiency. There were four votes for 80%, one with medium confidence, one with low confidence and two without a confidence rating. There was one vote for less than 80%, also without a confidence rating. The remaining votes were for “Don’t Know”. Due to the lack of confidence ratings, the RAG evidence rating has been changed from green to amber. One stakeholder believed that 80% should be the ambition, however another said that there needs to be differentiation from steel and aluminium targets from technical metals such as nickel, silver and gold.

[103] Stakeholder interviews

3.0 Measure 3 – Use of bio-based plastics

3.1 Electricals resource efficiency measure

3.1.1 Description

The increase in use of bio-based plastics in the design of products to reduce the use of fossil fuel-based plastics.

Bio-based plastics are plastics that are either fully or partially made from biomass, such as corn, sugarcane or cellulose. There are numerous types of bio-based plastics, some compostable, such as polylactic acid (PLA), some non-compostable, and many so-called ‘drop-in’ bio-based plastics that are chemically identical to conventional fossil-based polymers, such as bio-PA and bio-PP. The ‘drop-in’ polymers can therefore be used as direct replacements for virgin polymers without any degradation in product quality or performance, a useful complement to recycled content, which can on its own have a detrimental impact on product quality.

Lifecycle analysis shows that bio-based materials can (in certain situations) offer a reduction in carbon emissions across the whole lifecycle. However, there are other wider environmental concerns around agricultural inputs, and land-use competition, deforestation and biodiversity impacts.

3.1.2 Measure indicator

The indicator selected was the **percentage of bio-based plastic in place of fossil-based plastic**.

3.1.3 Examples in practice

There are a few examples of where bio-based plastics have been used in EEE. Beko, the appliance manufacturer, is using bio-based plastics in some of its products currently.

There are two types or bio-based plastics, which are drop-in polymers or novel polymers.

Drop-In Polymers:

Drop-in polymers such as, bio-PE or bio-PP share identical chemical structures and performance characteristics with traditional fossil-based plastics. This similarity allows them to seamlessly integrate into current processing and recycling systems. The appeal of drop-in bio-based plastics lies in their compatibility with existing infrastructure, without necessitating substantial changes to the plastics value chain or waste management systems. However, drop-in alternatives often have higher feedstock requirements, leading to increased land use compared to novel alternatives. Moreover, certain polymer types, such as polyvinyl chloride (PVC) and polystyrene (PS), currently lack commercially available drop-in substitutes.

Novel Polymers:

In contrast, novel polymers like polytrimethylene terephthalate (PTT) and polyethylene furanoate (PEF) offer a more innovative approach to bio-based plastics. PTT and PEF serve as alternatives to polyethylene terephthalate (PET), with barrier properties that make them suitable for food and beverage packaging. These novel bio-based polymers can demonstrate enhanced efficiency in converting bio-based feedstocks into plastics, which can result in reduced land use per tonne of plastic compared to fossil-based or drop-in alternatives. Despite their advantages, competing with established polymers like PET, which have established recycling routes, can be challenging, particularly in terms of price competitiveness. Striking a balance between compatibility with existing systems and maximising resource efficiency is crucial when considering the optimal mix of bio-based plastics.

3.2 Available sources

3.2.1 Literature review

The literature review identified twenty-one sources that discussed percentage content of bio-based plastics as a resource efficiency measure. These comprise:

- Eight website articles;
- Seven academic papers;
- Three technical studies; and
- Three industry reports.

Due to the high number of sources, they have been listed in Appendix C rather than as footnotes. The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.3 (out of 5), with sixteen sources exhibiting an IAS of 4 or above. One source exhibited an IAS of 2. One source was UK-specific, and seventeen of the sources were from the last ten years.

3.2.2 Interviews

Eight of the stakeholders interviewed commented on the use of bio-based plastics as a resource efficiency measure, discussing levels of efficiency and drivers and barriers for the different applications, depending on their area of expertise. The drivers mentioned by the stakeholders were carbon and cost savings, as well as consumer preferences for “greener” products. Similar to Measure 2, there were a number of barriers mentioned for Measure 3. There were comments on the bio-based plastics not having the same properties for like-for-like replacement, and the issue of recyclability was also mentioned. Product safety was another barrier mentioned. There was limited information provided on the levels of efficiency. At present, it is estimated that 3% of global bio-based plastics production goes into the EEE sector, with use being low across the sector more.

3.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 3. Overall, input from the stakeholders represented a decent coverage of the EEE sector, with discussions and votes being active from academics, social enterprises, a trade body, a thinktank, a producer compliance scheme and an NGO, however there was no representation from consumer electronics manufacturers. The majority of stakeholders that voted on the levels of efficiency gave a low confidence rating on the level provided, however no additional quantitative values were given. Stakeholders discussed the "green credentials" of bio-based plastics. When looking at the lifecycle assessments of the bio-based plastics, stakeholders did not believe bio-based plastic offered a more sustainable solution than fossil-based plastic.

The level of engagement in the workshop was as follows:

- Twelve stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Four stakeholders actively contributed to verbal discussion, and one stakeholder contributed on the Teams chat.

3.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

3.3.1 Drivers

Table 9 below shows the main drivers for Measure 3. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 9: Drivers for EEE Measure 3

Description	PESTLE	COM-B
Lower carbon footprint.[104] [105]	**Environmental**	**Opportunity – social**
Consumer appeal to use more ecofriendly products.[106]	**Social**	**Motivation – automatic**
Future legislations on tightening reduction in plastic waste.[107]	**Legal**	**Opportunity – social**

[104] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[105] Stakeholder interviews
[106] Stakeholder interviews
[107] Stakeholder interviews

Description	PESTLE	COM-B
Increasing range of bio-based plastic products.[108]	**Technological**	**Capability – physical**
Cost reduction.[109]	Economic	Opportunity – psychological

Lower carbon footprint

The use of renewable sources in place of fossil-based sources can result in a lower carbon footprint and overall environmental impact for the product,[110] without impacting the durability or recyclability of the product. One stakeholder from interviews gave the example of a German company who have obtained a 68% reduction in carbon emissions through the use of bioplastics to make their conductors.

Consumer demand for more sustainable products

Over the past few years there has been an increase in demand for sustainable products from consumers, and consumers are more aware of the environmental impacts of manufacturing of products. During the workshop there were eight votes out of fourteen for this consumer demand being among the top three drivers for Measure 3.

Future legislations on tightening reduction in plastic waste

The trend of tightening legislations on the reduction of plastic waste is likely to drive an increased adoption of bio-based plastics. Governments and regulatory bodies worldwide are becoming increasingly concerned about the environmental impact of plastic pollution, leading to the introduction of stricter regulations to address the issue. Bio-based plastics can be seen as an alternative that can align with any bans or restrictions that are implemented around fossil-based plastics. During the workshop there was one vote out of fourteen for future legislation being among the top three drivers for Measure 3.

Increasing range of bio-based plastic products

The development of bio-based plastics with diverse properties and characteristics makes them more and more suitable for a wide range of applications. During the workshop there were three votes out of fourteen for increasing range of products being among the top three drivers for Measure 3.

[108] Stakeholder interviews
[109] Stakeholder interviews
[110] European Bioplastics (2016) Bio-based plastics play an essential role in the future circular plastics economy. Available at: link

3.3.2 Barriers

Table 10 below shows the main barriers for Measure 3. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 10: Barriers for EEE Measure 3

Description	PESTLE	COM-B
Higher cost of bio-based plastics.[111] [112]	**Economic**	**Opportunity – social**
Concerns on feedstock for bio-based plastics and its impact on the environment.[113] [114] [115] [116] [117]	**Environmental**	**Opportunity – psychological**
Not all bio-based plastics can be recycled alongside traditional plastics.[118] [119]	**Technological**	**Capability – physical**
Trade-off between recycled fossil-based plastics and virgin bio-based plastics, including environmental impact, resource use and circularity.[120]	**Environmental**	**Motivation – reflective**
Food security requirements	Social	Capability – physical
Limited supply.[121] [122]	Technological	Capability – physical
Product Certification.[123]	Social	Capability – physical

[111] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[112] Stakeholder interviews
[113] TotalEnergies Corbon (2022) Sustainable sourcing of feedstocks for bioplastics. Available at: link
[114] Statista (2023) Estimated land use for bioplastics production worldwide from 2022 with a forecast to 2027. Available at: link
[115] European Bioplastics (2020) Fact Sheet: Bio-based plastics – fostering a resource efficient circular economy. Available at: link
[116] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[117] Stakeholder interviews
[118] Morao and de Bie (2019) Life cycle impact assessment of polylactic acid (PLA) produced from sugarcane in Thailand. Available at: link
[119] Stakeholder interviews
[120] Stakeholder interviews
[121] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[122] Yu et al. (2009) Ring-Opening Polymerization of L,L-Lactide: Kinetic and Modelling Study. Available at: link
[123] Stakeholder interviews

Description	PESTLE	COM-B
Substitution of materials does not always lead to improved environmental outcomes.[124]	Environmental	Motivation – reflective
Concerns on the thermal and electrical properties of conductive bioplastics.[125]	Technological	Capability – physical
High energy requirements in the fermentation process.[126]	Technological	Capability – physical
Lack of transparency from manufacturers.[127]	Economical	Capability – psychological
Concerns surrounding suitability for food contact and other safety requirements.[128]	Technological / Legal	Motivation – reflective

Cost of bio-based plastics

Many reports estimate current costs of common bio-based plastics such as bio-PET to be 10-30% higher than conventional plastic equivalents, although the range varies widely based on specific type and application.[129] [130] However, continued scale-up and technology advances are expected to reduce bio-based plastic costs over time. The cost of virgin fossil-based plastic is largely influenced by oil and gas prices, which fluctuate. During the workshop two out of the twenty-six voted were for cost being one of the top three barriers for Measure 3.

Impact of feedstock on the environment

If traditional food crops like corn, sugarcane or soybeans are used as feedstocks for bio-based plastics, it could incentivise conversion of new land for agriculture production, which in turn can affect biodiversity and terrestrial carbon sinks and have an impact on food security. Overall, while bio-based plastics can offer sustainability benefits, their scalability should be paired with assessments of associated land use trade-offs to ensure responsible sourcing. A diversity of feedstocks and agricultural integration will be key. During the workshop, nine out of the twenty-

[124] Stakeholder interviews
[125] Kong et al. (2023) The Potential Applications of Reinforced Bioplastics in Various Industries: A Review. Available at: link
[126] Stakeholder interviews
[127] Stakeholder interviews
[128] Stakeholder interviews
[129] Cho, R. (2017) The Truth About Bioplastics. Available at: link
[130] Institute of Bioplastics and Biocomposites (N.D.) Are bioplastics more expensive than conventional petro-based plastics? Available at: link

six voted for concerns regarding land use competition and biodiversity being one of the top three barriers for Measure 3.

Recyclability

Bio-based feedstocks can be used to create a variety of polymers as can fossil-based feedstocks. Different feedstocks can be used to create the same final polymer with physical and chemical characteristics that are almost indistinguishable. Where a bio-based or fossil-based feedstock are used to make the same end polymer that happens to be recyclable, it will be recyclable from either feedstock (i.e., feedstock is independent of the recyclability itself, it is the final polymer and associated characteristics that dictate recyclability). During the workshop, three out of the twenty-six votes were for recyclability being one of the top three barriers for Measure 3.

Trade-off between recycled fossil-based plastics and virgin bio-based plastics, including environmental impact, resource use and circularity.

Recycling fossil-based plastics can reduce the demand for new raw materials, decrease energy consumption and lower greenhouse gas emissions compared to producing virgin plastics. However, the recycling process itself can have environmental impacts, including energy use and the release of certain pollutants. Bio-based plastics are derived from renewable resources, such as corn or sugarcane. The production of bio-based plastics may have a lower carbon footprint compared to fossil-based plastics. However, it is essential to consider land use, water consumption and potential impacts on biodiversity associated with the cultivation of bio-based feedstocks. In the workshop three of the twenty-six voted were for this barrier being one of the top three barriers for Measure 3.

3.4 Levels of efficiency

Table 11: Levels of efficiency for EEE Measure 3

Indicator: % of bio-based plastic in place of fossil-based plastic			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	Less than 1%	100%	10%
Evidence RAG	Amber	Red	Red

3.4.1 Current level of efficiency

It is unclear from the literature what the percentage is of bio-based plastics used across EEE. Beko has stated that the egg trays used in their refrigerators are made up of 80% bioplastic, which is however only one element of a large appliance.[131] Dell have stated that they are looking to incorporate bio-based plastics into their products, aiming for 50% of their product content to be made from recycled or renewable materials by 2030.[132] However, it is unclear what percentage of this could be from bio-based plastics or what they are currently achieving. It was estimated in 2015 that 1% of all plastics on the market were bio-based and it was predicted to be 3% by 2020.[133] This was for the global market and so it is unclear what portion of this was used for EEE. One stakeholder in interviews stated that 3% of global bio-based plastics goes into EEE products and other stakeholders agreed that the use of bio-based plastics is very low. Because of this it was initially estimated that less than 1% of EEE placed on the market currently contains bio-based plastic.

During the workshop, six of the seventeen stakeholders voted on the current level of efficiency for Measure 3, consisting of academics, thinktanks, producer compliance scheme and an NGO. There was a good coverage and representation across the EEE sector. Of those that voted, three voted for less than 1% with medium confidence. There was one vote for less than 5% with low confidence. There were two votes for “Don’t Know”. Overall, stakeholders tended to agree with the current level of efficiency being less than 1%. The stakeholder that suggested less than 5% gave a low confidence rating and therefore has not impacted the current level of efficiency. The current RAG evidence rating for this is amber, and that will remain the same based on the two votes of medium confidence. The current level of efficiency figure will therefore remain at less than 1%.

3.4.2 Maximum level of efficiency in 2035

A large proportion of consumer electrical appliances are made of plastics. Today, casings, circuit boards and data storage are made of plastic to ensure the appliances are light and durable. The potential to replace conventional plastics with bio-based plastics is 100% in theory, although the overall impact on the EEE market is hard to assess.

In small household appliances and consumer equipment the composition of plastic is around 35%, in IT and telecommunications it is around 25%, in electrical and electronic toys its 45% and in leisure and sports equipment plastic makes up almost 70%.[134] Globally, there is 2.2 million tonnes of bio-based plastics being placed on the market, 66,000 tonnes of which can be used in EEE.[135] There is a great amount of scope for all these items to contain bio-based plastics instead of fossil fuel-based plastics. Some stakeholders during the interviews indicated that the maximum level of efficiency was lower, at up to 60%.

In the workshop, nine of the seventeen stakeholders voted on the maximum level of efficiency – consisting of two academics, one producer compliance scheme, one manufacturer, and NGO, a social enterprise and a trade association. There was therefore moderate representation from the EEE sector. Of the nine stakeholders that voted, four voted for a

[131] Beko (2023) Waste is no longer a problem, it's a resource! Available at: link
[132] Dell (N.D) Driving innovative products and solutions for a more sustainable future. Available at: link
[133] Karvinen, H. (2015) Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics. Available at: link
[134] Bacher et al. (2017) Future Trends in WEEE Composition and Treatment - A Review Report. Available at: link
[135] European Bioplastics (2023) Applications for Bioplastics. Available at: link

maximum level of efficiency of less than 100%, all with low confidence. No further information to quantify the exact level of efficiency was provided. There were two votes for “Other” with low confidence and a further two votes for “Don’t Know”. Due to the votes of low confidence the RAG evidence rating has been moved from amber to red. One stakeholder stated that there was not enough biomass for potential applications of bio-based plastics, which could prevent the uptake. Several stakeholders also stated that this was not their area of expertise and so could not confidently estimate what the level should be. The use of bio-based plastics is relatively newer than other practices that are being looked at in EEE.

3.4.3 Business-as-usual in 2035

Some businesses are moving into the use of bio-based plastics and hence the proportion used will almost certainly increase due to corporate commitments. Stakeholders agreed that there is an observed effort to replace fossil-based plastic with bio-based plastic, with one interviewed stakeholder indicating that they aim to incorporate 5% bio-based plastics by 2030, with other stakeholders indicating that they believe the level could increase to 20%. Apple have already highlighted that they now have seventeen components made from bio-based plastic, and it is increasingly common for bio-based plastic to be used in EEE.[136] While specific usage across the EEE sector is difficult to quantify, the growing focus on sustainability and interest from major brands indicates that bio-based plastics will likely increase. However, the scale of adoption will depend on continued innovation and supply chain development to allow confidence is supply and sourcing, as well as addressing performance/cost considerations.

Based on the trends towards increased use of bio-based plastics a figure of 10% was initially estimated based on interviews with stakeholders and literature.

In the workshop, eight of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of two academics, one producer compliance scheme, one manufacturer, and NGO, a social enterprise and a trade association. There was therefore a good representation from the EEE sector. There were three votes for 10% being the business-as-usual level of efficiency, all with a low confidence rating. There was one vote for between 11% to 20%, again with a low confidence rating. There was one vote for other and two votes for “Don’t Know”. The level for business-as-usual is currently 10%, with a red RAG evidence rating. The findings and votes from the workshop seem to reflect this and so have these level of efficiency and RAG evidence rating have remained. Again, many stated this was not their area of expertise, and another said there should be a focus on biodiversity and food security over the creation of bio-based plastics.

[136] Apple (2021) Environmental Progress Report. Available at: link

4.0 Measure 4 – Increasing material yield and reincorporating waste during manufacture

4.1 Electricals resource efficiency measure

4.1.1 Description

The overall reduction in unavoidable waste generated during manufacturing, through a combination of increased material yield and reincorporation of waste created during the manufacturing process as direct feedstock for a process, reducing primary resource use.

This Measure can also be known as Lean manufacturing, utilising methods such as Six Sigma and statistical process control. Lean manufacturing is a production process based on an ideology of maximising productivity while simultaneously minimising waste within a manufacturing operation. Six Sigma is a set of methodologies and tools used to improve business processes by reducing defects and errors, minimising variation and increasing quality and efficiency. The efficiency of product manufacturing techniques and processes can impact material yields and, thus, the quantity of waste generated. Various manufacturing stages can be optimised to improve resource efficiency.

Waste is generated at many stages during the manufacturing process and across the supply chain, to create the final product. Where the generation of this waste cannot be avoided, the next preferred resource efficiency measure is to ensure that the waste can be reused or recycled within the process directly, or through other external recycling routes (see Measure 9).

4.1.2 Measure indicator

The indicator selected for this Measure is the **percentage of input raw materials that successfully make it in EEE products, considering material losses throughout the supply-chain**. This can be accomplished by increasing material yield, which may involve reincorporating waste back into the manufacturing process as feedstock.

The more material that is recovered and reincorporated during the manufacturing process reduces the amount of material that is either landfilled, incinerated or recycled. This can reduce the amount of material that is treated as waste, which can subsequently reduce operating costs and carbon emissions.

4.1.3 Examples in practice

Several manufacturers interviewed noted that they own or control their manufacturing in Europe, Turkey and the Far East and are very active on Lean and Six Sigma production efficiency approaches, whilst also modernising production methods to reduce material waste in manufacturing (from machining for example). 3D printing was only mentioned in the context of rapid prototyping rather than mainstream manufacture. It was noted that recycling of material within the process, or within the supply chain, is standard, for example allowing plastic injection moulding waste 'regrind' to be put back into moulding, and scrap metal to be reformed in casting.

Apple offers a good example of a company that has been trying to minimise the amount of waste produced from their facilities and their supplier facilities. They have been working towards waste free operations where they aim to send nothing to landfill. In 2015, Apple launched a zero-waste programme for their manufacturing partners. In 2020, 100% of Apple's assembling facilities were Zero Waste Certified (90% of waste is recycled or composted), with 70% of suppliers achieving the certification in 2020. To minimise the amount of waste produced, Apple have worked on solutions such as broadening the use of Recyclable Protective Film, which protects products during manufacturing and prevents items from sustaining defects or damages, therefore preventing them from becoming waste. Additionally, many of the materials used in the products are being captured and returned to the general market, for example the cobalt from iPhone batteries is extracted by Apple's own machines and is returned then to the market to be used in other products.[137]

4.2 Available sources

4.2.1 Literature review

The literature review identified ten sources that discussed Increasing material yield and reincorporating of waste during manufacture as a resource efficiency measure. These comprise:

- Four academic papers;
- Three website articles;
- Two technical studies; and
- One industry report.

Literature sources have been listed in Appendix C rather than as footnotes. The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.6 (out of 5), with five sources exhibiting an IAS of 4 or above. No sources were UK-specific, and nine of the sources were from the last ten years.

[137] Apple (2021) Environmental Progress Report. Available at: link

4.2.2 Interviews

Seven of the stakeholders interviewed commented on increasing material yield and reincorporating of waste during manufacture as a resource efficiency measure, discussing levels of efficiency and drivers and barriers for the different applications, depending on their area of expertise. The drivers mentioned included cost and carbon savings. One interviewee mentioned that there should be standards and a minimum expectation from manufacturers to reincorporate waste during manufacturing. There were no barriers mentioned. When discussing levels of efficiency, only one interviewee provided percentages, with current the level being close to 100% and maximum level being 100% of the reincorporation of manufacturing waste. Another interviewee stated that there currently is good practice for the reincorporation of waste, again providing further evidence that the current efficiency levels are already quite high.

4.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 4. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academics, social enterprises, a trade body, a thinktank, a producer compliance scheme and an NGO. The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current, maximum and business-as-usual levels of efficiency. Stakeholders discussed the difficulty with measuring this as most of the large manufacturers work at a global scale, as well as what policy approaches could help minimise waste.

The level of engagement in the workshop was as follows:

- Fifteen stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion and one stakeholder contributed on the Teams chat.

4.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

4.3.1 Drivers

Table 12 below shows the main drivers for Measure 4. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 12: Drivers for EEE Measure 4

Description	PESTLE	COM-B
Cost savings.[138] [139]	**Economic**	**Opportunity – physical**
Reduction in greenhouse gas emissions and energy consumption.[140] [141]	**Environmental**	**Opportunity – social**
Reducing demand for virgin resources and reducing waste by capturing production waste for placing back into the production process. [142] [143]	**Environmental**	**Motivation – automatic**
Increase in national WEEE policy, legislation, or regulation.[144]	**Political**	**Motivation – automatic**
Green credentials for organisations.	**Social**	**Opportunity – social**

Cost Savings

Waste reduction often involves streamlining processes and identifying inefficiencies. By optimising operations, businesses can increase productivity and reduce costs associated with unnecessary steps or resource wastage. Additionally, disposal of waste often comes at a cost and processing and disposing of waste can also be energy intensive, leading to both carbon savings and cost reductions. In the workshop, eight out of nineteen votes for the top three drivers were for cost savings.

Reduction in greenhouse gas emissions and energy consumption.

By using resources more efficiently, businesses can reduce the need for energy-intensive manufacturing processes, leading to lower overall energy consumption and associated emissions. Increasing yield and minimising waste contributes to energy and emission savings by promoting more efficient resource use, reducing the environmental impact of manufacturing

[138] Delta Impact (2023) How to improve operational efficiency in electronics manufacturing. Available at: link
[139] Stakeholder interviews
[140] Golzary and Abdoli (2020) Recycling of copper from waste printed circuit boards by modified supercritical carbon dioxide combined with supercritical water pre-treatment. Available at: link
[141] Stakeholder interviews
[142] Golzary and Abdoli (2020) Recycling of copper from waste printed circuit boards by modified supercritical carbon dioxide combined with supercritical water pre-treatment. Available at: link
[143] O'Connor et al. (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[144] Forti et al. (2020) The Global E-waste Monitor 2020: Quantities, flows, and the circular economy potential. Available at: link

and transportation, and encouraging sustainable practices throughout the product lifecycle. In the workshop, five out of nineteen votes for the top three drivers were for this driver.

Reducing demand for virgin resources and reducing waste by capturing production waste for placing back into the production process

There has been a reduction in the demand for virgin resources across manufacturers and consumers. Additionally, many organisations are moving towards a zero waste as they are increasingly aware of the emissions and environmental impact related to both waste production and extraction of virgin resources. In the workshop, three out of nineteen votes for the top three drivers were for this driver.

Increase in national WEEE policy, legislation, or regulation

Since 2014, the number of countries that have adopted a national WEEE policy, legislation, or regulation has increased from 61 to 78.[145] In the future there is likely to be an increase in policies, legislation or regulations, particularly around WEEE, which will stimulate the move towards higher yields and incorporation of waste back into the manufacturing process. In the workshop three out of nineteen votes for the top three drivers were for this driver.

4.3.2 Barriers

Table 13 below shows the main barriers for Measure 4. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 13: Barriers for EEE Measure 4

Description	PESTLE	COM-B
Cost of construction for Lean design.[146]	**Economic**	**Opportunity – social**
Supply chain relationships.[147]	**Social**	**Opportunity – social**
Lack of understanding among companies in the supply chain on how to develop circular economy implementation roadmaps.[148]	**Technological**	**Capability – psychological**

145 Forti et al. (2020) The Global E-waste Monitor 2020: Quantities, flows, and the circular economy potential. Available at: link
146 Amazon (2023) Manufacturing Optimization for the Electronics Industry: How to Accelerate Product Development and Drive Engineering Efficiency with Instrumental Inc. on AWS. Available at: link
147 Workshops
148 Bressanelli et al. (2021) Enablers, levers and benefits of Circular Economy in the Electrical and Electronic Equipment supply chain: a literature review. Available at: link

Description	PESTLE	COM-B
Inconsistent optimisation among different actors along the supply chain.[149]	**Technological**	**Capability – physical**
Lack of control from brands if contract manufacturers are used.[150]	**Technological**	**Capability – physical**
Lack of testing / industry experience.[151]	**Technological**	**Capability – psychological**

Cost of lean manufacturing production machinery

Optimisation of processes may require upgrade and/or development of current processes and machinery or technology. This can require significant investment from manufacturers which may be too much in comparison to the relative cost savings it will deliver – i.e., will offer a long payback period on the investment. In the workshop two out of seventeen votes for the top three barriers were for this barrier.

Supply chain relationships

Building strong and collaborative relationships within the supply chain is crucial for advancing the circular economy. Circular practices often involve the cooperation of various stakeholders to optimise resource use, reduce waste and promote sustainable processes. In the workshop seven out of seventeen votes for the top three barriers were for this barrier.

Lack of understanding among companies in the supply chain on how to develop circular economy implementation roadmaps

Some companies may lack awareness and understanding of circular economy concepts and their potential benefits. Whilst some of the larger manufacturers might have sustainability teams other smaller companies may not resulting in a potential knowledge gap. Circular economy requires systematic support from all levels of the supply chain to implement circular economy principles. In the workshop two out of seventeen votes for the top three barriers were for this barrier.

Inconsistent optimisation among different actors along the supply chain

Inconsistent optimisation among different actors along the supply chain is a common challenge that can hinder overall efficiency and sustainability efforts. It often arises due to variations in priorities, goals and strategies among different stakeholders. Insufficient collaboration among

149 Amazon (2023) Manufacturing Optimization for the Electronics Industry: How to Accelerate Product Development and Drive Engineering Efficiency with Instrumental Inc. on AWS. Available at: link
150 Stakeholder interviews
151 Stakeholder interviews

supply chain actors can result in missed opportunities for joint optimisation, as well as incompatible technologies and systems. In the workshop four out of seventeen votes for the top three barriers were for this barrier.

4.4 Levels of efficiency

Table 14: Levels of efficiency for EEE Measure 4

Indicator: % of input raw materials that successfully make it in EEE products, considering material losses throughout the supply-chain			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	75%	90%	80%
Evidence RAG	Amber	Amber	Amber

4.4.1 Current level of efficiency

Yield rates can vary largely based on product category, manufacturing processes used, industry sector and individual manufacturer. Generally, yield rates tend to be fairly high, since there is a cost driver, although larger companies tend to be better placed to track and prevent material wastage in production than small to medium-sized enterprises (SMEs) who may have fewer resources. Material yields in EEE manufacturing tend to range from around 60% to 90% based on estimates in academic studies and sustainability reports.[152][153] Stakeholders in the interviews agreed that current levels of efficiency are high, and that reducing and reincorporating waste is current practice for economic reasons. A current efficiency level of 75% was initially estimated because of this.

In the workshop, six of the seventeen stakeholders voted on the current level of efficiency – consisting of one academic, one producer compliance scheme, one manufacturer, one NGO, one trade association and one social enterprise. There was therefore good representation from the EEE sector. Of the six stakeholders that voted, three voted that the current level was 75% with medium confidence, and one voted for less than 75% again with medium confidence. There were two votes for “Don’t Know”. Overall, the stakeholders that voted tended to agree with the current level of efficiency being 75%. During the discussion, one stakeholder mentioned that Japanese manufacturers have been working on zero waste for many years, and so their global factories will have waste minimisation as a “red line”. They also noted that some of the smaller manufacturers will have different pressures and may not have Lean manufacturing processes and programmes in place, and so may not be able to achieve these

[152] Apple (2021) Environmental Progress Report. Available at: link
[153] Golzary and Abdoli (2020) Recycling of copper from waste printed circuit boards by modified supercritical carbon dioxide combined with supercritical water pre-treatment. Available at: link

levels of efficiencies. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 4 is 75%, with an amber RAG evidence rating.

4.4.2 Maximum level of efficiency in 2035

Production waste in the manufacturing of PCBs was mentioned in the literature, with copper being a waste material from the process. One study found that copper extraction efficiency from PCB manufacture was found to reach 97% under the correct conditions, thereby preventing the creation of waste and reincorporating the captured copper back into the process.[154] In addition, Apple have achieved a 90% recycling and composting rate in 100% of their assembly facilities shows that it is possible to reduce waste produced during production and increase yield of products.[155] One stakeholder in the interviews agreed that this has the potential to be very high, reaching close to 100%.

In the workshop, six of the seventeen stakeholders voted on the maximum level of efficiency – consisting of one academic, one producer compliance scheme, one manufacturer, one NGO, one trade association and one social enterprise. There was therefore good representation from the EEE sector. Of the six stakeholders that voted, two voted that the maximum level of efficiency was 90% with medium confidence, the others voted for "Don't Know". One of the "Don't Know" votes did add that 90% is possible with incentives and infrastructure support from SMEs. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency for Measure 4 is 90%, with an amber RAG evidence rating.

4.4.3 Business-as-usual in 2035

Whilst there a lack of literature on the production efficiency and yield rates for business-as-usual, it is safe to assume that it would at least increase from the current levels of efficiency. The global generation of WEEE will increase from 53.6 million tonnes (2019) to 74.7 million tonnes (2030), and there will likely be increasing pressure to minimise the amount of waste produced by EEE either through the manufacturing/production stage or post-consumer stage.[156] Manufacturers will inevitably want to reduce costs and maximise yields and therefore increases in production efficiency will happen naturally, particularly as newer manufacturing plant comes online.

In the workshop, eight of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of academics, one producer compliance scheme, one manufacturer, one NGO, one trade association and one social enterprise. There was therefore good representation from the EEE sector. Of the eight stakeholders that voted, four voted for a business-as-usual level of efficiency of 80% with medium confidence. The four remaining votes were for "Don't Know". One stakeholder added that, whilst not their area of expertise, they

[154] Golzary and Abdoli (2020) Recycling of copper from waste printed circuit boards by modified supercritical carbon dioxide combined with supercritical water pre-treatment. Available at: Link
[155] Apple (2021) Environmental Progress Report. Available at: link
[156] Forti et al. (2020) The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. Available at: link

could see that there are economic drivers to incentivise companies to increase yield and reincorporate waste back into manufacturing. Overall, stakeholders tended to agree with the business-as-usual level of efficiency, and so it has remained at 80% with a RAG evidence rating of amber.

5.0 Measure 5 – Repair and refurbishment

5.1 Electricals resource efficiency measure

5.1.1 Description

Repair and refurbishment enable the restoration of non or poorly functioning products back to a working and satisfactory state. This in turn extends a product lifetime, if only temporarily. This delays, and potentially avoids, the purchase of new products.

Repair consists of fixing a fault and/or replacing a defective component in a product, making the product fully functional. This allows the product to be used for its originally intended purpose. Similarly, refurbishment consists of modifying a product to restore its performance and/or functionality according to certain technical standards or regulatory requirements. This allows the product to be fully functional for at least one of its originally intended purposes. In both cases, the lifespan of the product is extended.[157] Repair and refurbishment do not, however, provide the consumer with a guarantee that the product is like new, nor does it provide the same level of warranty as an equivalent new or remanufactured product.[158] The repair and refurbishment process can include isolated repairs of specific broken elements and does not generally involve full dismantling of the product. Refurbishment can consist of cleaning the product (both physically and digitally via data cleansing) and testing its functionality. For some products, preventative maintenance prevents a fault from occurring. An analogy is that regular car maintenance can keep a car running efficiently and prevent major faults from developing. Similarly, Portable Appliance Testing (PAT) of certain electrical appliances can be carried out at regular intervals to ensure electrical appliances are operating correctly and safely without need of repair or replacement.

Maintenance, repair and refurbishment increases resource efficiency by increasing the lifetime of products and therefore reducing the demand and consumption of new products. However, the success of this is dependent on consumer awareness, engagement and their perceptions of repaired and refurbished products. Furthermore, the suitability of an item for repair or refurbishment is heavily dependent on the design of the product, which influences the ability to access faulty components, the cost of repair and the availability of spare parts. Currently, as per the UK Ecodesign Regulations 2021, manufacturers of specified electrical products are obliged to provide repair information and spare parts to professional repairers for a specified amount of time after the product has been placed on the market and again once it has been discontinued.[159]

It should be noted that durability and reliability are closely related aspects, with very reliable and durable products not requiring repair, although they may still need refurbishment (and

[157] Oakdene Hollins (2022) A Study of the Potential of VRPs for Resource Efficiency. Available at: link
[158] IRP (2018) Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. Available at: link
[159] UK Government (2021) The Ecodesign for Energy-Related Products and Energy Information Regulations 2021. Available at: link

upgrade) to allow continued use. The Ellen MacArthur Foundation describes two aspects of durability:[160]

- Physical durability – the material choices, construction, component reinforcement etc. needed to create durable products that resist damage; and
- Emotional durability – strategies that increase and maintain the product's relevance and desirability to user(s) over time.

These aspects of durability were often mentioned by stakeholders and are discussed qualitatively throughout the section.

5.1.2 Measure indicator

The indicator that was selected was the **percentage of EEE products in use that are repaired or refurbished**. The repair and refurbishment of products extends product lifetime and therefore prevents the purchase of new products temporarily, thereby reducing overall consumption over time.

It is recognised that the repair or refurbishment of one used EEE product may not necessarily displace the purchase of one new EEE product – i.e., it is unlikely that there would be a 1:1 displacement rate. This can be for many reasons, such as: the lifespan of the repaired/refurbished EEE may be lower than that of a new EEE, so the repaired/refurbished EEE may be replaced sooner; a consumer may only consider purchasing refurbished EEE (i.e., they would not have purchased the EEE as "new"); or a consumer may continue to purchase an additional new EEE product along with the repaired product. During the workshop, one stakeholder explained that they used a 50% reduction factor when estimating carbon emission savings from repaired EEE. However, no further information was provided as to what categories of EEE this was for or why 50% was applied. As such, the assumption is that the repair or refurbishment of one used EEE product will avoid the purchase of between a half to one new EEE products – i.e., a displacement rate of between 1:1 to 1:2.

Another indicator that was common in the literature was the percentage of consumers that have utilised repair services. This indicator was not taken forward since use of a service does not necessarily result in resource efficiency savings.

5.1.1 Examples in practice

There are numerous methods by which maintenance, repair and refurbishment services can be delivered for EEE. The extent to which these services are used vary depending on the product type, the extent of repair or refurbishment required, the age of the product and the comparative cost of replacement with a newer version. Pathways for repair and refurbishment include:

- Retailer and original equipment manufacturer (OEM) returns, soon after purchase, where the item may be unboxed.

[160] Ellen MacArthur Foundation (2021) Design products to be used more and for longer. Available at: link.

- Self-repair services conducted by consumers themselves, including guidance from repair instructions obtained directly form the OEM, via a third party (e.g., online videos, such as those from iFIXIT), or with the help of a repair café.
- Under-warranty repair services, delivered by the OEM or an approved service agent.
- Under extended warranty (usually provided by an insurance company for a retailer), delivered by an approved service agent working for the insurance company.
- Post-warranty, by an OEM-approved service agent or by an independent repairer (often small businesses or sole traders).

GXO ServiceTech, based in Greater Manchester, for instance, offers an extensive range of EEE warranty repair, reverse logistics, refurbishment and resale services, as a third-party provider to various OEMs and retailers. Asset recovery services let the company refurbish returned goods to ‘as new’ or ‘graded’ standard for resale.[161] Another provider offering a similar service is AP Taylor.[162]

Apple collect used products via a trade in scheme and resell them as certified refurbished products with a one-year warranty.[163] In 2019, they refurbished 11.1 million devices.[164]

Hewlett Packard Enterprise runs a large IT equipment refurbishment centre (the Renewal Centre) in Erskine, Scotland, where they carry out refurbishment of donated used computers and network equipment. The equipment is tested, data-wiped and then sold to consumers as pre-owned products.[165] In 2019, they remarketed 1.21 million units of hardware.[166] Between the Erskine centre and other renewal centres in Andover, Massachusetts, Hewlett Packard Enterprise processes more than 4 million IT assets per year, with 88% being refurbished, 12% being recycled and less than 1% going to landfill in 2020 data.[167]

The WEEE recycler and AATF, GAP, based in Northeast England have expanded their services to refurbishment of WEEE, specialising in used EEE. Part of the Gap Renew service, a team of skilled technicians refurbish and repair products to high-quality standards and recycles products that cannot be refurbished. Gap Renew offers comprehensive services throughout the entire product lifecycle; from collection and assessment to refurbishment and resale.[168]

Farnham Repair Café operates a local repair café in Hampshire, England, that has to date carried out over 80 repair workshops/sessions (once per month).[169] Around 3,000 items have been handled, of which around 50% were small EEE, and of which about 50% were fixed at

[161] GXO ServiceTech (2023) What We Do: GXO ServiceTech. Available at: link
[162] AP Taylor (2023) Helping you realise the full potential of sustainable returns solutions. Available at: link
[163] Apple (2023) Certified Refurbished. Available at: link
[164] Aydin and Mansour (2023) Investigating sustainable consumer preferences for remanufactured electronic products. Available at: link
[165] McKenna, B. (2019) HPE refurbishes legacy IT assets to make money for users. Available at: link
[166] Aydin and Mansour (2023) Investigating sustainable consumer preferences for remanufactured electronic products. Available at: link
[167] Hewlett Packard (2019) Living Progress Report 2019. Available at: link.
[168] GAP Group (2023) GAP Renew. Available at: link.
[169] Farnham Repair Café (2023) Farnham Repair Café. Available at: link.

close to zero cost. The café utilises the local engineering skills of (often retired) people in the community, whilst also providing a social environment for these people While such repair cafes offer a valuable community service, the scale of operations is very small compared to the commercial operations noted above.

5.2 Available sources

5.2.1 Literature review

The literature review identified thirty-seven sources that discussed repair and refurbishment as a resource efficiency measure. These comprise:

- Eleven academic papers;
- Ten website articles;
- Nine industry reports;
- Four technical studies; and
- Three policy documents.

Due to the high number of sources, they have been listed in Appendix C rather than as footnotes. Literature sources have been listed in Appendix C rather than as footnotes. The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.3 (out of 5), with twenty-eight sources exhibiting an IAS of 4 or above. Fourteen sources were UK-specific, and thirty-five of the sources were from the last ten years.

5.2.2 Interviews

Fourteen of the stakeholders interviewed commented on repair and refurbishment as a measure to improve resource efficiency in the EEE sector. This high level of engagement highlighted numerous drivers and barriers. Stakeholders from manufacturers to academics to trade associations, recognised the importance of ‘right to repair’ legislation for consumers, but that increased consumer awareness did not necessarily lead to much higher levels of repair. Also important in the discussion was the drive to make high quality parts available to consumers, either at the point of sale or via skilled and/or approved repairers. Commonly raised barriers included the high expense for consumers, either in purchasing a more physically durable (and therefore higher priced) product, or in the high cost of repairs for anything from white goods to small electricals. Also highlighted was the mirrored expense for producers to develop and manufacture more durable products, and the lack of tax and VAT incentives on repaired or refurbished products. Many stakeholders agreed that legislation was important to lower these barriers and drive levels of repair and refurbishment up.

5.2.3 Workshop

Measure 5 received the highest level of engagement of all measures in the workshop. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being input from academics, a social enterprise, a thinktank and an NGO. However, manufacturers for consumer electronics were absent. One stakeholder suggested that this Measure ought to be differentiated into repair and refurbishment separately, since both have distinct policy drivers and barriers. The same stakeholder suggested that discussion of refurbishment may sit better in Measure 8 (remanufacture) as they saw refurbishment is a form of remanufacture. This point, was discussed in the course of the research and for the purpose of this report, refurbishment was established as distinct from remanufacture as it does not fully restore a product to “like new” status, often accompanied by a shorter warranty period than a remanufactured product (further discussion can be found in section 8.0 Measure 8 – Remanufacture). The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current, maximum and business-as-usual level of efficiency, however, no quantified levels were provided.

The level of engagement in the workshop was as follows:

- Ten stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Four stakeholders actively contributed to verbal discussion, with five stakeholders contributing on the Teams chat.

5.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

5.3.1 Drivers

Table 15 below shows the main drivers for Measure 5. The most substantial drivers are shown in bold as voted for by stakeholders in the workshop.

Table 15: Drivers for EEE Measure 5

Description	PESTLE	COM-B
Repair and refurbishment can be cheaper for the consumer than replacing the whole product.[170] [171] [172] [173]	**Economic**	**Motivation – reflective**
Increased consumer awareness surrounding the environmental benefits of repair compared with replacement.[174] [175]	**Environmental**	**Motivation – automatic**
Improved brand reputation, with consumers likely to repurchase with the same manufacturer if they experienced a positive repair experience.[176]	**Social**	**Opportunity - social**
Modularity, design for repair and the opportunity to upgrade during refurbishment if desired.[177] [178]	Technological	Capability – physical
Regulations for the provision of spare parts for a minimum period, repair instructions, and the use of commonly available tools.[179] [180] [181] [182] [183]	Legal	Motivation – automatic
Presence of repair cafes, making repair a more convenient, accessible and attractive option for people. They also offer upskilling and a social experience, adding further benefit.[184]	Social	Opportunity – social
Potential for additional revenue for businesses.[185]	Economic	Opportunity – psychological

[170] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[171] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[172] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[173] Stakeholder interviews
[174] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[175] Stakeholder interviews
[176] Green Alliance (2015) A circular economy for smart devices. Available at: link
[177] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[178] Stakeholder interviews
[179] UK Government (2021) The Ecodesign for Energy-Related Products and Energy Information Regulations 2021. Available at: link
[180] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[181] Rawnsley, J. (2023) Is a sustainable electronics industry possible? Available at: link
[182] Green Alliance (2015) A circular economy for smart devices. Available at: link
[183] Stakeholder interview
[184] Stakeholder interviews
[185] Stakeholder interviews

Description	PESTLE	COM-B
Safety requirements imposed on professional repairers.[186]	Technological	Capability – physical
Emotional design, and a consumer's emotional connection with the product, including potential for personalisation and uniqueness.[187]	Social	Motivation - reflective
Timeless design increasing acceptance by consumers and the use of materials that age well.[188] [189]	Technological	Capability – physical

5.3.2.1 Key drivers

More cost efficient for the consumer

In some cases, particularly with higher value EEE, repairing or purchasing refurbished products can be cheaper than purchasing new EEE, especially if only one part of the EEE needs repairing to bring it back to a functioning and satisfactory condition. For manufacturers and third parties, this also presents a new market opportunity and customer base of consumers that repair or purchase refurbished EEE due to economic and/or environmental reasons. Six of the twenty-six votes for the top three drivers in the workshop were for this driver. This was the highest voted driver amongst workshop stakeholders.

Increased consumer awareness of the environmental benefits of repair

Consumers can be encouraged to have a positive attitude towards refurbished or repaired products if they are given information about the environmental benefits associated with them.[190] Five of the twenty-six votes for the top three drivers in the workshop were for this driver.

Improved brand reputation

In a survey conducted by the repair website company iFixit, 95% of consumers said that successful repair makes them more likely to buy another product from the same manufacturer.[191] Electrical goods brands could take advantage of this increased brand loyalty by offering repair and refurbishment. Five of the twenty-six votes for the top three drivers in the workshop were for this driver.

Repair accessibility and Modular Design

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186 Stakeholder interviews
187 Stakeholder interviews
188 Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
189 Stakeholder interviews
190 Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
191 Green Alliance (2015) A circular economy for smart devices. Available at: link

The design of products to make key internal components easily accessible and replaceable is an enabler of repair and refurbishment practices, both at home and through a professional service.[192] [193] [194]

One study looked into the impact of modular design on repair rates.[195] The study found that 55% of conventional smartphones were not repaired, whereas only 13% of modular devices were not repaired. Furthermore, it found that fewer modular devices required professional services to be repaired (35%), compared to semi-modular devices (61%). Three of the twenty-six votes for the top three drivers in the workshop were for this driver.

5.3.2.2 Additional drivers

Legislation requiring the provision of spare parts.

The UK Ecodesign Regulations mandate that, for certain EEE, manufacturers must provide repair information and spare parts to professional repairers. Spare parts must be available within two years of the product being placed on the market and must be available for seven to ten years after the product has been discontinued. Additionally, there is a maximum delivery timeframe of fifteen working days, in which the manufacturer, importer or authorised representative must deliver the spare parts from receiving the order. There is also the requirement to provide a procedure for ordering spare parts and to be able to repair products with non-specialised tools.[196] EEE subject to the requirement for making spare parts available include:

- Refrigeration appliances – e.g., lighting, starting relays, thermostats and door handles.
- Household dishwashers – e.g., drain pumps, heating elements, electronic displays and door seals.
- Household washing machines and washer-dryers – e.g., motors, pumps, washing drum and door locking assembly.
- Electronic displays – e.g., power supply, connectors, DVD modules and remote controls.

5.3.2 Barriers

Table 16 below shows the main barriers for Measure 5. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 16: Barriers for EEE Measure 5

[192] Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
[193] CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
[194] Rawnsley, J. (2023) Is a sustainable electronics industry possible? Available at: link
[195] Amend et al. (2022) The potential of modular product design on repair behavior and user experience – Evidence from the smartphone industry. Available at: link
[196] UK Government (2021) The Ecodesign for Energy-Related Products and Energy Information Regulations 2021. Available at: link

Description	PESTLE	COM-B
Consumer concerns surrounding warranty, data protection, quality, safety and lifetime of repaired and refurbished products.[197] [198] [199] [200] [201] [202]	**Technological**	**Motivation – automatic**
Technological obsolescence, with a lack of interoperability between old hardware and new software.[203] [204]	**Technological**	**Capability – physical**
Economic obsolescence, where the cost of repair is higher than replacement.[205] [206] [207] [208] [209] [210] [211]	**Economic**	**Capability – physical**
Lack of industry-wide quality standards to confirm the repaired and refurbished product meets certain criteria.[212]	Legal	Capability – psychological
Lack of availability and difficulty accessing spare parts or repair manuals. [213] [214] [215] [216] [217] [218]	Technological	Capability – physical

[197] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[198] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[199] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[200] MMR (2023) Refurbished Electronics Market: Global Industry Analysis and Forecast (2023-2029). Available at: link
[201] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[202] Stakeholder interviews
[203] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[204] Stakeholder interviews
[205] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[206] Rawnsley, J. (2023) Is a sustainable electronics industry possible? Available at: link
[207] DSS (2022) Development of policy options for resource efficient eco-design of energy-related products. Available at: link
[208] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[209] Bovea et al. (2017) Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. Available at: link
[210] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[211] Stakeholder interviews
[212] Stakeholder interviews
[213] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[214] Rawnsley, J. (2023) Is a sustainable electronics industry possible? Available at: link
[215] Green Alliance (2015) A circular economy for smart devices. Available at: link
[216] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[217] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[218] Bovea et al. (2017) Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. Available at: link

Description	PESTLE	COM-B
Products not designed for repair or durability.[219] [220] [221]	Technological	Capability – physical
Purchasing a new product can be perceived as more convenient (in time and effort) than repairing or refurbishing an existing product.[222]	Social	Opportunity – social
Some repaired EEE may cost more to operate than new EEE based on efficiency ratings, resulting in a higher overall cost to the consumer.[223]	Economic	Capability – physical
Higher end products that are designed for repairability and durability can be more expensive and less accessible to consumers.[224]	Technological	Opportunity – psychological
Lack of technical capability and skilled staff, and the variety in product design across models means different methods are required.[225] [226] [227] [228] [229]	Technological	Capability – physical
Lack of support to develop repair networks and cafes.[230]	Social	Motivation – automatic
Lack of information surrounding product history and the repair or refurbishment cycles that have already been undertaken, such as the ESPR in the EU.[231]	Technological	Capability – physical

[219] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[220] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[221] Stakeholder interviews
[222] Güsser-Fachbach et al. (2023) Repair service convenience in a circular economy: The perspective of customers and repair companies. Available at: link
[223] Hischier and Böni (2021) Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study. Available at: link

[225] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[226] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[227] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[228] Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
[229] Stakeholder interviews
[230] Stakeholder interviews

Description	PESTLE	COM-B
OEMs reducing functionality if repair activities are carried out by third parties.[232]	Technological	Capability – physical
Perceived obsolescence, where consumers consider their product outdated or unfashionable due to technological advances and trends. [233]	Social	Opportunity – social
Risk of damaging products when transporting to and from retailers and refurbishment facilities.[234]	Technological	Capability – physical
Social stigma around buying used and concern over quality and product history.[235] [236]	Social	Motivation – automatic

5.3.1.1 Key barriers

Consumer perceptions and attitudes

One of the main barriers towards the increase in uptake of repair services is the negative consumer perception of the repair and refurbishment process. This ranges from the perception that second-hand repaired products are inferior compared with new products; concerns about data security when handing over their products to be repaired; and a lack of understanding of the processes, leading to concerns surrounding functionality and lifetime of repaired and refurbished products.[237] An increase in education and awareness surrounding the process of repair and refurbishment and the identification of competent professional repairers were identified as enablers that would make consumers more confident in the process. Six of the twenty-nine votes for the top three drivers in the workshop were for this driver. This was the highest voted driver amongst workshop stakeholders.

Technical obsolescence

A lack of interoperability between old hardware and new software is a barrier for repair and refurbishment.[238] [239] If electronics are no longer supported with important software updates,

[232] MacAneney, M. (2018) If It Is Broken, You Should Not Fix It: The Threat Fair Repair Legislation Poses to the Manufacturer and the Consumer. Available at: link.
[233] European Environment Agency (2023) Europe's consumption in a circular economy: the benefits of longer-lasting electronics. Available at: link
[234] DSS (2022) Development of policy options for resource efficient eco-design of energy-related products. Available at: link
[235] Weelden et al. (2016) Paving the way towards circular consumption. Available at: link
[236] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[237] Güsser-Fachbach et al. (2023) Repair service convenience in a circular economy: The perspective of customers and repair companies. Available at: link
[238] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[239] Stakeholder interviews

the product will become unusable regardless of the longevity of the actual hardware. Five of the twenty-nine votes for the top three drivers in the workshop were for this driver.

Cost of repair

Another common barrier is the cost of repair. For the consumer, this becomes a barrier when the cost of repair is not economically attractive in comparison with the cost of a new product. One stakeholder suggested that in some cases (such as older products) the cost of repair can be up to 25% of the price of a new product. Consumers may also prefer the option of buying a new product. For manufacturers and repairers, this becomes a barrier when the labour and parts required to conduct the repair are uncompetitive with the cost of new products. Four of the twenty-nine votes for the top three drivers in the workshop were for this driver.

5.3.1.2 Additional barriers

Lack of availability of spare parts

Despite the legislative requirements for manufacturers to provide access to spare parts, lack of availability was the most commonly identified barrier to repair and refurbishment. Indefinite storage of used EEE by consumers, both functional and non-functional, was a barrier to the supply of feedstock of used spare parts.

Lack of comprehensive Right to Repair and other supporting legislation in the UK

Although the Ecodesign Regulations 2021 require the provision of spare parts and repair information for a minimum length of time for certain product categories, more extensive ‘right to repair’’ legislation that ensures that repair is prioritised over replacement is lacking. For example, the EU have recently adopted a new proposal for a Directive on common rules promoting the repair of goods.[240] This proposal aims to ensure that more products are repaired within the legal guarantee and that consumers have easier and cheaper options for repair available to them, even when the legal guarantee has expired.

Furthermore, France, who are currently the only country to have done so, have enacted their own law that mandates the display of clear information for consumers on the repairability of five categories of EEE (smartphones, laptops, televisions, washing machines and lawnmowers), which is displayed via the Repairability Index on the product. The objective of this Index is to encourage consumers to choose more repairable products, and manufacturers to improve the repairability of their products.[241] The aspects that are assessed in the Index are documentation, ease of disassembly, availability of spare parts, price of spare parts and other product specific aspects. These specific aspects can include software aspects, for example, for smartphones. The EU institutions are showing increasing support for the consumer right to repair, particularly the Repairability Index.

[240] European Commission (2023) Proposal for a Directive on common rules promoting the repair of goods. Available at: link
[241] Right to Repair (2021) The French repair index: challenges and opportunities. Available at: link

5.4 Levels of efficiency

Table 17: Levels of efficiency for EEE Measure 5

Indicator: % of EEE products in use that are repaired or refurbished			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	10%	70%	15%
Evidence RAG	Green	Green	Amber

5.4.1 Current level of efficiency

The current level of efficiency for Measure 5 varies depending on the product. Quantitative data in the literature were mainly available for personal mobile devices and household EEE, such as mobile phones, tablets, e-books, laptops and other small household appliances.

With reference to personal mobile devices, such as mobile phones, laptops, tablets and cameras, there was consensus in the literature that the current rate of repair and refurbishment (mainly in reference to number of consumers who have utilised this service) is at a maximum of 10%.[242] For mobile phones specifically, sources ranged from 5% of the market being made up of used or refurbished [243] to 9% of consumers having purchased second-hand/refurbished mobile phones.[244] Both of these sources were UK specific and exhibited an IAS of 4. A further source that extends to laptops and tablets as well quoted that 10% of consumer currently opt to repair their devices,[245] with this source also being specific to the UK with an IAS of 4.

For Europe, two sources both agreed that 10% of the European phone market is made up of used or refurbished mobile phones [246] and that there is a 10% refurbishment rate of mobile phones.[247] These sources exhibit an IAS of 4 and 5 respectively. However, another source quotes a lower figure that only 6% of mobile devices in Europe are restored, refurbished and remarketed.[248] This source also exhibits a high IAS of 5.

In support of these low figures, a further source states that 65.5% of consumers have never utilised repair on their personal mobile devices.[249] This source exhibits an IAS of 5 and in

[242] Green Alliance (2015) A circular economy for smart devices. Available at: link
[243] Gillet and Pratty (2022) Money for old phones — but can the refurb boom last? Available at: link
[244] Assurant (2021) Growth of Interest for Refurbished Devices. Available at: link
[245] Green Alliance (2015) A circular economy for smart devices. Available at: link
[246] Gillet and Pratty (2022) Money for old phones — but can the refurb boom last? Available at: link
[247] Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
[248] Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
[249] Bovea et al. (2018) A survey on consumers' attitude towards storing and end-of-life strategies of small information and communication technology devices in Spain. Available at: link

relation the Spanish market, meaning that is it likely to be applicable to the UK. Therefore, it was assumed with a relatively high level of confidence that the current use of repair services for personal mobile devices would be 10%.

With reference to small household EEE appliances, one source states that the rate of repair is low, with 9.6% of consumer having taken small EEE to be repaired.[250] As above, this source exhibits an IAS of 5 and is in relation to the Spanish market, so is reasonable to apply to the UK market. It can therefore be assumed that, similarly to personal mobile devices, the repair rate of small household EEE is 10%.

Expanding this to include all household EEE appliances, so to include washing machines, fridges, and dishwashers etc., one source looked specifically into the reduction in number of products placed on the market (POM) if a 50% extension to the product lifetime was assumed. This source provided an average of 10% reduction across seventeen common household EEE appliances.[251] This source was specific to the UK and exhibits an IAS of 4. Similarly, it stated that a 6% reduction in WEEE generated would also result. Although the source does not explicitly state that this lifetime extension was a result of carrying out repair or refurbishment activities, it can be reasonably assumed that a large proportion of the devices required some element of repair to extend their lifetime by 50%. This figure is in line with the previous product categories and sources so can be taken with a high level of confidence.

However, a final study that focussed on a wide range of EEE categories found that 13.3% of consumers had repaired defective EEE themselves (highest for small household appliances and tools and equipment) and 29.59% of consumers had reported using specialised services to repair defective EEE (highest for large household appliances and computer equipment).[252] However, this source, although it has an IAS of 5, is focussed on Romania, which exhibits lower income than the UK which could explain the differences in consumer attitudes.[253] As this data demonstrates, repair services are more common for large appliances where there is a more favourable trade-off between the cost of repair and the cost (and convenience) of replacement. For example, large household appliances can be expensive to purchase so replacement may not be the most favourable option. Similarly, there is a trade-off between reliability and durability, and repairability, where manufacturers may design products to be more reliable, but at the expense of the repairability of the product. For example, bearings may be sealed and inaccessible in the drum of the washing machine, which improves durability but makes repair difficult. The same study also demonstrated that the use of repair is low, with 62% of consumers choosing to replace a product when it breaks down, even if it is still deemed repairable.[254]

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[250] Bovea et al. (2017) Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. Available at: link
[251] DSS (2022) Development of policy options for resource efficient eco-design of energy-related products. Available at: link
[252] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[253] Wisevoter (2023) Poorest Countries in Europe. Available at: link
[254] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link

Stakeholder interviews agreed that although there is evidence of many manufacturers offering free repairs within the warranty service, and that it is common for consumers to buy extended warranties, the current level of efficiency is low, but could not provide any quantitative data. However, some stakeholders were of the view that repair for major domestic appliances was significantly higher as a product category, in part driven by their significant cost. One stakeholder gave the example of the low level of usage of repair cafes and their lack of scale beyond a community movement. However, another stakeholder highlighted that repair cafés have a 66% overall success rate for full repair and an 85% to 90% partial repair rate (it was noted that electricals represent approximately half of the items brought to repair cafes and that the repair rates for electricals is slightly lower than the overall averages quoted here). The cost of repair compared with the cost of replacement was highlighted through stakeholder interviews as a major barrier, with one stakeholder suggesting that consumers are not willing to pay any more than 25% of the cost of replacement when considering repair. This consideration is further exaggerated as products get older and the consumer’s desire to replace is higher. Another stakeholder also highlighted that there is a trade-off for manufacturers in keeping spare parts available (large inventories of spare parts are required unless they can be 3D printed) and the consumer’s desire to repair.

It can be reasonably assumed that the extension of life through the use of repair or refurbishment results in an overall reduction of new product purchases. Therefore, it was initially estimated that the current level of efficiency was approximately 10% across the whole EEE sector, with a green RAG evidence rating due to agreement among sources.

In the workshop, seven of the seventeen stakeholders voted on the current level of efficiency – consisting of two academics, one social enterprise, one producer compliance scheme, one manufacturer, one thinktank and one trade body. There was therefore good representation from the EEE sector. Of the seven stakeholders that voted, five voted for a current level of efficiency of 10%, four voting with medium confidence and one voting with low confidence. Two stakeholders voted for a greater than 10% level of efficiency with low confidence. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 5 is assumed to be 10%, with a green RAG evidence rating.

5.4.2 Maximum level of efficiency in 2035

When compared to the current level of efficiency, fewer sources contained quantitative data on the maximum level of efficiency. Due to technical and safety considerations, it is not feasible to repair or refurbish 100% of items that become defective, especially if they have been utilised for a long period of time. As with the current level of efficiency, the maximum level of efficiency varies depending on the product category, with factors such as aesthetics, design obstacles and availability of new features, for example, impacting some products more than others. For example, consumers may be more likely to want to repair their washing machine or fridge due to the cost of purchasing a new one and the similar functionality of a newer version. In comparison, when a consumer’s mobile phone becomes faulty or breaks, newer models and features may drive the consumer to replacement instead of repair.

One study focussed specifically on discarded microwaves from households in the UK.[255] PAT testing findings indicated that 8% of them were not safe to repair. The majority (74%) could be repaired, with only 22% of them having minor cosmetic imperfections. The remaining 17% were found to be functional and suitable for direct reuse (see Measure 8). This source exhibits an IAS of 5.

Another study looked into the number of successful repairs that were carried out when requested by the consumer. The study found that 91% of repair requests could be fulfilled for home appliances and that 95% could be fulfilled for white goods.[256] However, although these figures may be high, the availability of products for repair is dependent on the decision of the consumer to repair and is therefore not representative of this indicator. Similarly, a final source indicated that 80% of washing machines were fully functional after repair.[257]

Stakeholders at interview also agreed that the maximum level of efficiency for repair is very high, with one stakeholder stating that 100% of consumer goods could be repaired if this figure were to exclude those unsuitable for repair due to safety reasons.

Therefore, it was initially estimated that the maximum level of efficiency for repair, excluding those products suitable for direct reuse and those unsafe to repair, could be approximately 70%, with a green RAG evidence rating. However, this would be dependent on the removal of barriers detailed above.

In the workshop, seven of the seventeen stakeholders voted on the maximum level of efficiency – consisting of two academics, one social enterprise, one producer compliance scheme, one manufacturer, one thinktank and one trade body. There was therefore good representation from the EEE sector. Of the seven stakeholders that voted, five voted for a maximum level of efficiency of 70%, two voting with high confidence, two with medium confidence and one voting with low confidence. The two remaining votes were for “Don’t’ Know”. One stakeholder said there are clear areas where pro-repair policies could stimulate a stronger repair economy, and two other stakeholders suggested the maximum level could be higher than 70% if the right drivers, such as appropriate standards to guarantee safety and sufficiently trained repair engineers, are in place. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency for Measure 5 is 70%, with a green RAG evidence rating.

5.4.3 Business-as-usual in 2035

One source stated that the global refurbished electronics market is set to increase by 79% (from US$235 billion to US$421.43 billion) by 2029, with Europe consisting of roughly 33% of this market.[258] However, it must be noted that the global repair market does not accurately

[255] Dindarian et al. (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
[256] DSS (2022) Development of policy options for resource efficient eco-design of energy-related products. Available at: link
[257] DSS (2022) The eco-modulation of producers’ financial obligations for WEEE in the UK. Available at: link
[258] MMR (2023) Refurbished Electronics Market: Global Industry Analysis and Forecast (2023-2029). Available at: link

reflect the UK market as many discarded EEE products are exported for repair in developing countries, where the demand for cheap and lower specification products is high.[259] The exception is the repair or refurbishment of products to a like-new status (not including warranty associated with a new product – see Measure 9) which is already being observed in the UK. For example, the refurbished phone, laptop and other personal electronics market, and large appliances to some extent, has increased drastically in recent years and has become more established.

Overall, there was consensus amongst stakeholders that the amount of repair, and therefore the prevention of purchase of new products, will naturally increase towards 2030 due to the increased demand from more environmentally conscious consumers. For example, research by Kantar Group suggests the sales of refurbished smartphones is increasing by 24% year on year.[260] Higher figures were provided for small and major household appliances, with other stakeholders agreeing with this by stating that the sector is only mainly relevant to white goods and screens. Others stated that there is limited growth potential for the repair of EEE and that there is reluctance from the industry. Other stakeholders stated that the only thing that will encourage the uptake of the repair sector will be legislative drivers, indicating that the business-as-usual scenario will not increase substantially.

Therefore, in the absence of any quantitative data, it can be assumed that the rate of repair and therefore the subsequent prevention of purchasing of new products, will increase only slightly under a business-as-usual scenario. Although consumer attitudes may develop slightly, the cost of repair and ease of replacement means that it will require major change to become the preferred option for most consumers. Therefore, a level of efficiency of 15% was initially estimated, with red RAG evidence rating.

In the workshop, eight of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of three academics, one social enterprise, one producer compliance scheme, one manufacturer, one thinktank and one trade body. There was therefore good representation from the EEE sector. Of the eight stakeholders that voted, six voted for a business-as-usual level of efficiency of 15%, three voting with high confidence, two with medium confidence and one voting with low confidence. The two remaining votes were for greater than 15% with a low confidence level. One stakeholder remarked that there would be little progress in the business-as-usual scenario under the current legislative landscape. Another stakeholder agreed, saying that the UK Government would need to support a system of repair to include safety, design for repair, legislation such as repairability labelling or digital passports and in local skills development for repair/refurbishment engineers. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the business-as-usual level of efficiency for Measure 5 is 15%, with an amber RAG evidence rating. This increase from red to amber RAG evidence rating is based on consensus from stakeholders at the workshop, who mostly voted with high or medium confidence.

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[259] Krings, H. (2015) International Trade in second-hand electronic goods and the resulting global rebound effect. Available at: link
[260] Kantar Group (2023) Refurbished technology gains popularity as a cost-saving choice. Available at: link

6.0 Measure 6 – Rental and collaborative consumption models

6.1 Electricals resource efficiency measure

6.1.1 Description

The increase in uptake and market penetration of rental or products-as-a-service business models by consumers and businesses can reduce consumption and increase product lifetimes.

For many EEE products, consumers purchase the product outright, which can lead to high rates of consumption and limited requirement to return the product at its end-of-use for reuse, repair, refurbishment or even recycling. Certain EEE have specific technical uses and so may not be used regularly by consumers. Such rarely or infrequently used EEE (such as power tools and party sound and lighting equipment) are therefore appropriate for circular economy business models, such as short-term rental (e.g., tool hire). Opportunities for leasing particularly exist in the B2B sector, where companies require large quantities of EEE. For example, a large number of vacuum cleaners may be leased by a commercial cleaning company, or a large number of laptops and network equipment may be leased by offices and data centres.

Rental and leasing therefore drive resource efficiency by keeping products and materials in use for as long as possible (durability, reuse and repair) and through maximising the utilisation of products (multiple users renting short-term use of a product). This is in contrast to the single-owner, linear economy business model, which can result in less durable products being used a limited number of times. Product ownership remains with the producer or the third party, and they have the incentive to ensure that durable products are used and that servicing/maintenance is optimised and reuse, repair and refurbishment is maximised so as to extend life and reduce costs across several contract hires.[261] Such models were historically very common, in the 1960s to 1980s, when items like colour televisions were expensive and unreliable, with companies offering long term rental and other services.

As with Measure 5, durability and reliability is a key enabler for success in this Measure. and as such, durability is discussed qualitatively throughout the section.

6.1.2 Measure indicator

The indicator that was selected was the **percentage of EEE products in use via circular economy business models and collaborative consumption**. This contributes to resource efficiency by decreasing the number of new products required to achieve the same level of

[261] Suppipat and Hu (2022) A scoping review of design for circularity in the electrical and electronics industry. Available at: link

use. Since one product can be rented or leased by multiple users over the product's lifetime, this reduces the number of products that are manufactured.

It is recognised that the rental of one EEE product may not necessarily displace the purchase of one new EEE product – i.e., it is unlikely that there would be a 1:1 displacement rate. This can be for many reasons, such as the short-term rental of an EEE product only temporarily delaying the purchase of a new product. Alternatively, the short-term lease of one EEE product by many consumers may avoid multiple consumers each purchasing a new EEE product. However, there was no evidence identified from the EEE sector suggesting a more suitable displacement rate. As such, the assumption is that the rental of one EEE product will avoid the purchase of one new EEE product – i.e., a 1:1 displacement rate.

6.1.3 Examples in practice

There are a number of different types of circular economy business models that can be utilised:[262]

- Pay for use, where customers are purchasing the output of a product and pay based on a metric, such as hours used.
- Leasing, where customers buy contractual rights to the use of a product over a specified period of time, usually with exclusive access over several months or years.
- Rental, where customers buy the rights to use a product, usually in a less formal contractual agreement than leasing and for a shorter period of time.
- Product-as-a-Service (PaaS), where customers buy rights (e.g., under a subscription) to the use of a product over a period of time, with additional services included – such as repair and replacement.
- Performance agreement, where customers buy a pre-defined service and level of quality that companies commit to guaranteeing.

There are certain products that are better suited to the rental and PaaS sector. Tool hire, such as carpet cleaners or chainsaws, for example, are rarely needed in domestic settings and are expensive to purchase outright. Tools are therefore widely hired from tool hire businesses. Similarly, plant hire is common for construction equipment, such as concrete mixers and cranes.[263] The rental of commercial laundry and dishwashing equipment is also common. For example, the manufacturer, Miele, offers a 60-month rental contract for its cleaning products, that includes regular maintenance.[264] Numatic currently offers a lease service for its professional cleaning equipment.[265] One stakeholder noted that they were considering the introduction of an appliance leasing programme for housing associations and private landlords who will often require a large quantity at regular intervals.

[262] Lacy and Rutqvist (2015) The Product as a Service Business Model: Performance over Ownership. Waste to Wealth. Available at: link
[263] Travis Perkins (2023) Tool hire. Available at: link.
[264] Miele (2023) Rental solutions. Available at: link.
[265] Numatic (2023) Leasing solutions. Available at: link.

It is important to note that lease and rental, while costly on a per-use basis, avoids consumers needing to fund high capital expenditure. Leasing offers a predictable cost on a regular basis, and with a service plan, avoids any concerns around breakdowns or costs of unplanned maintenance. A common example of this in this sector is mobile phones. For consumers that pay monthly contract deals, these mobile phones are, in effect, leased to the consumer with additional services such as mobile data and call time. At the end of the lease period, the mobile phone can be traded in for the next lease agreement. However, due to the fast-paced technological development, particularly in the mobile phone industry, the devices often have lower residual value at the end of the contract but can be repaired or refurbished and used for resale or remanufacturing.

6.2 Available sources

6.2.1 Literature review

The literature review identified fifteen sources that discussed rental and collaborative consumption models as a resource efficiency measure. These comprise:

- Six website articles;
- Four academic papers;
- Four industry reports; and
- One technical study.

Literature sources have been listed in Appendix C rather than as footnotes. Literature sources have been listed in Appendix C rather than as footnotes. The relevant sources were considered of high applicability and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.5 (out of 5), with six sources exhibiting an IAS of 4 or above. Four sources were UK-specific, and eight sources were from the last ten years.

6.2.2 Interviews

Twelve of the stakeholders interviewed commented on alternative consumption models in the EEE sector. There was a general consensus that progress in this area has thus far been slow, and that the default desire by consumers is to own their EEE products, even if rental models in one form or another have existed and worked well historically. Some stakeholders commented that this ownership default was down to the low cost of many EEE products, and that rental models would be much more viable for more expensive products that would provide overall savings to the customer over ownership and provide access to higher quality goods to consumers with less to spend. It was recognised that there is a consumer drive for more sustainable goods, but that cost would be the key driver for consumers considering rental models. Stakeholders suggested that there was also a reluctance on the part of EEE producers to provide alternatives due to the complex business strategies required, and the risk of lending goods that could be easily misused or stolen by the consumer. All in all, stakeholders remarked that the quality of products provided was key to a successful rental market, so that consumers could trust the quality of the rented goods and providers could trust that the products would withstand use from multiple users.

6.2.3 Workshop

Measure 6 received a high level of engagement in the workshop. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being input from academics, a trade association, a producer compliance scheme, a manufacturer, a social enterprise, a thinktank and an NGO. One stakeholder expressed a concern that the levels of efficiency for this Measure would differ greatly between product type. This is a valid point that has been considered in the course of the research for many of the measures, since the sector covers a vast range of products and industries. However, for consistency across the different measures it was deemed appropriate to present a general level of efficiency for the whole industry, even if the RAG evidence rating is poor as a result of uncertainty due to variations between product types.

The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current level of efficiency. As for the business-as-usual and maximum levels of efficiency, most stakeholders believed the levels of efficiency would be higher than proposed. However, no quantified levels were provided.

The level of engagement in the workshop was as follows:

- Eleven stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Seven stakeholders actively contributed to verbal discussion and two stakeholders contributed on the Teams chat.

6.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

6.3.1 Drivers

Table 18 below shows the main drivers for Measure 6. The most significant drivers are shown in bold as voted for by stakeholders in the workshop.

Table 18: Drivers for EEE Measure 6

Description	PESTLE	COM-B
Lower upfront costs for consumers compared to purchasing outright.[266] [267] [268]	**Economic**	**Motivation – automatic**
Consumer convenience may be improved due to maintenance and repair services included in PaaS model.	**Social**	**Opportunity – social**
Consumers have access to up-to-date products at a more affordable ongoing cost.[269]	**Technological**	**Motivation – automatic**
Product ownership stays with the owner lease company.	Social	Motivation – automatic
Availability of sharing platforms.	Technological	Motivation – automatic
Digitalisation.	Technological	Motivation – automatic
Ongoing subscription costs beneficial for cash-flow and consumer lock-in in rental and leasing companies.	Economic	Motivation – automatic
Incentivises durable and repairable products, allowing for increased revenue from each product.[270] [271]	Technological	Capability – physical
Consumers are not responsible for end-of-use treatment/disposal.[272]	Technological	Motivation – automatic
Second-hand use in other industries (e.g., textiles) triggering behavioural change in EEE.	Environmental	Opportunity – physical

[266] Business Owner's Playbook (2023) Lease, Don't Buy, Capital Equipment. Available at: link
[267] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[268] Stakeholder interviews
[269] Alexander, P. (2005) Should You Lease or Buy Your Tech Equipment? Available at: link
[270] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[271] Stakeholder interviews
[272] Business Owner's Playbook (2023) Lease, Don't Buy, Capital Equipment. Available at: link

Description	PESTLE	COM-B
Brand loyalty may be gained by consumers renewing rental and leasing agreements.	Social	Opportunity – social
Returned end-of-use products provides manufacturers with an opportunity to sell as a used product, use parts for repair and remanufacture, or recycle appropriately.[273] [274]	Technological	Motivation – automatic

6.3.1.1 Key drivers

Lower upfront costs for consumers

One of the main drivers for the use of rental and PaaS services is that consumers are not required to pay the upfront cost that they would with purchasing the product outright. This can be particularly relevant for products that consumers do not use very often and for higher cost products. Although the cost per use may still be high for the short-term rental, it is lower than purchasing the product outright. Six out of the twenty-five votes for the top three drivers in the workshop were for this driver. This was the highest voted driver amongst workshop stakeholders.

Improved consumer convenience

Consumers may benefit from improved convenience if the burden of maintenance and repair is placed on the lease provider.[275] Four out of the twenty-five votes for the top three drivers in the workshop were for this driver.

Up-to-date and high-quality products at a more affordable ongoing costs for consumers

Leasing electrical equipment allows consumers to stay up-to-date with the newest equipment, passing the burden of obsolescence onto the lease provider.[276] When a lease expires, consumers can upgrade their equipment to a newer, faster, or cheaper alternative. Similarly higher quality products may become more affordable with a spread cost as noted earlier. Four out of the twenty-five votes for the top three drivers in the workshop were for this driver.

6.3.1.2 Additional drivers

Product ownership stays with the owner lease company

[273] Green Alliance (2015) A circular economy for smart devices. Available at: link
[274] Stakeholder interviews
[275] Stakeholder interviews
[276] Alexander, P. (2005) Should You Lease or Buy Your Tech Equipment? Available at: link

The use of rental or leasing presents benefits to manufacturers and asset management companies that provide rented or leased equipment. The main benefit is that it potentially allows for the owning companies to have closer control over optimised maintenance, thereby increasing product lifetimes and reuse opportunities. Digital diagnostic and condition monitoring systems linked via the internet are a key element of this. However, there are limitations caused by data protection laws and security concerns over household system 'hacking'. Takeback, after several lease or rental periods, can also guarantee access to end-of-life products that can supply parts for repair and remanufacture or recycling.

Availability of sharing platforms

The availability of digital platforms that enable formal and informal leasing and sharing, such as those that have recently developed for second-hand products (e.g., Depop and Vinted), are an enabler to increase uptake of circular economy business models. For example, the development and promotion of the 'library of things' (an initiative that lends products to the public), within local communities will make these types of service offerings more accessible and more likely to be considered by consumers. Toy libraries offer another example.

Digitalisation

An increasingly digitalised society and industry will enable the creation and expansion of circular economy business models. As well as sharing platforms, items can be digitally tracked and their condition monitored to help optimise servicing, for example, and establish when they need replacement under a lease contract for example.

6.3.2 Barriers

Table 19 below shows the main barriers for Measure 6. The most significant barriers are shown in bold as voted for by stakeholders in the workshop.

Table 19: Barriers for electrical Measure 6

Description	PESTLE	COM-B
Complex business model that requires a change in business strategy and investment.[277] [278]	**Economic**	**Opportunity – social**
Desire from consumers to own their own products outright, particularly for products that consumers depend on for everyday use.[279]	**Social**	**Opportunity – social**

[277] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[278] Stakeholder interviews
[279] Stakeholder interviews

Description	PESTLE	COM-B
Competition with cheaper products that do not have circular benefits hinders scale up.[280]	**Economic**	**Motivation – automatic**
Potentially higher lifetime costs for the consumer depending on the length of the lease term, compared with the price of purchasing new.[281] [282]	Economic	Motivation – automatic
Lack of trust and understanding from consumers on the process for certain products.[283]	Social	Motivation – automatic
Lack of legislation concerning durability, including Repairability Index, which will enable the rental sector.[284]	Legal	Motivation – automatic
Risks of consumer misuse and theft associated with informal sharing, but also in formal lending scenarios.[285]	Social	Motivation – automatic
Reluctance of traditional product providers to switch to rental models since repaired and resold goods are taxed at the point of every sale, meaning disproportionate taxation for businesses due to VAT.[286]	Economic	Motivation – automatic
Takes flexibility away from consumers to choose alternative models or brands by locking into a contract.[287]	Social	Motivation – automatic

6.3.2.1 Key barriers

Requires a change to current business models

[280] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[281] Business Owner's Playbook (2023) Lease, Don't Buy, Capital Equipment. Available at: link
[282] Stakeholder interviews
[283] Stakeholder interviews
[284] Stakeholder interviews
[285] Stakeholder interviews
[286] Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
[287] Stakeholder interviews

Being able to offer circular economy business model services will require business to make drastic changes to their current services and model. Current business models work on the basis that the manufacturer or third-party seller receive the full price of the product at the point of sale. However, in leasing business models the income is spread over a longer period of time and cash flow therefore needs to be handled differently. This will require high levels of willingness and investment as well as buy in from investors and shareholders. Six out of the twenty-four votes for the top three drivers in the workshop were for this driver. This was the highest voted driver amongst workshop stakeholders.

Consumer desire to own products

There is a general perception that consumers prefer to own products outright, particularly for products that get frequent use.[288] This poses a psychological barrier for consumers who may not consider renting or sharing products due to this preference, and the convenience of having a product that can be used at short-notice, even if it may not be used frequently. Five of the twenty-four votes for the top three drivers in the workshop were for this driver.

Competition with cheaper products

The relatively low outright costs of some consumer electrical goods is such that it is not economically viable to choose a leased alternative. As cheap goods are easily available, this is a barrier to reducing the consumption of leased items. During the workshop, one stakeholder suggested that until the price of new goods goes up, sharing and leasing models will never reach a mainstream market and will remain the niche option for just a few consumers. Five of the twenty-four votes for the top three drivers in the workshop were for this driver.

6.3.2.2 Additional barriers

Higher overall cost to the consumer

Depending on the length of the lease, which will be dependent on the product and the intended use of the product, it may cost the consumer significantly more to rent over the lifetime of the product rather than buying it outright.

Consumer attitudes

At present, consumers are unaware of or do not consider the use of circular economy business models. For example, a Repic survey found that 77% of consumers would not consider leasing EEE, although this could be dependent on the product in question.[289]

[288] Stakeholder interviews
[289] Stakeholder interviews

6.4 Levels of efficiency

Table 20: Levels of efficiency for EEE Measure 6

Indicator: % of EEE products in use via circular economy business models and collaborative consumption			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	1 – 5%	20 – 40%	5 – 20%
Evidence RAG	Red	Red	Red

6.4.1 Current level of efficiency

The level of efficiency for this Measure will vary drastically depending on the product type and on the end user. For example, the leasing of office equipment and IT assets is not uncommon and there are businesses in existence that facilitate the leasing of this type of equipment, such as 3StepIT.[290] The uptake of these types of business model in this category of consumer will be significantly higher, with one source stating that 39% of businesses claim that they lease at least some of their equipment.[291] This source exhibits an IAS of 4 and is relevant to the US market in 2016. It can therefore be applied with high confidence to the UK market.

Conversely, other sources that focussed on non-commercial consumers ranged from 1% [292] to 5% [293] when discussing the number of people that have leased, rented or borrowed products, with borrow being the highest. The second source also reported that 21% of EEE users stated that they share certain EEE with other people.[294] Although it was not specified, this could extend to the use of computers or printers, for example, within their household or in community centres or public libraries rather than renting of leasing a product for personal use. Both of these sources exhibit an IAS of 5, with the former being focussed on Europe and the latter on Romania. As discussed in Measure 6, the differently levels of wealth between the UK and Romanian consumer may influence these consumer decisions.

Stakeholder interviews agreed that the current level of consumer uptake in these business models was very low, with not much uptake being observed and the business models still unproven. This was consistent across input from small domestic appliances, major domestic appliances and EEE in general. One stakeholder highlighted that it may be higher for certain

[290] 3StepIT (N.D.) Sustainable Technology Lifecycle Management. Available at: link
[291] Business Owner's Playbook (2023) Lease, Don't Buy, Capital Equipment. Available at: link
[292] Parajuly et al. (2020) Behavioral change for the circular economy: A review with focus on electronic waste management in the EU. Available at: link
[293] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[294] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link

consumer products, such as construction tools, but that collaborative consumption is not the first option that consumers consider when requiring a new product. Other stakeholders indicated that it may have increased slightly in recent years, particularly in business-to-business, but that there been limited uptake within business-to-consumer when manufacturers have trialled the business model.

Therefore, due to the differences in product category, it was initially estimated, with an amber RAG evidence rating, that the current level of efficiency ranged was between 1% to 15%, with consumer electronics at the lower end of the range, and with B2B IT equipment, and white goods, at the upper end of the range.

In the workshop, eight of the seventeen stakeholders voted on the current level of efficiency – consisting of three academics, two thinktanks, one producer compliance scheme, one manufacturer and one trade body. Of the eight stakeholders that voted, seven voted for a current level of efficiency of 1-5% with low confidence. One stakeholder voted for a greater than 6-15% level of efficiency with medium confidence. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 6 is 1-5%. Since the majority of stakeholders voted with a low level of confidence, the RAG evidence rating has been reduced from amber to red.

6.4.2 Maximum level of efficiency in 2035

There was no quantitative data found in the literature that indicated what the maximum technical level of efficiency would be for these types of businesses models.

Stakeholder interviews suggested the maximum level is dependent on the product in question, and that those products with the most potential are in categories that consumers do not use very often, for example, power tools and other construction equipment, and seasonal products such as fans and cooling equipment. Another stakeholder indicated that these business models will only become practical once the product has reached a plateau in its technological development. For example, certain IT equipment such as displays are not likely to develop to offer better functionality quickly, and are therefore better candidates for this type of business model. Similar logic can be applied to large household appliances such as fridges and washing machines. Stakeholder input ranged from 30% when considering all EEE products, to 80% when considering domestic appliances.

B2B lease and rental was agreed to offer far more potential than business-to-consumer (B2C), although the level that is attainable is hard to judge. Xerox offers one example. In geographies where Xerox exercises direct control over the end-of-life management of equipment, return rates are high, with approximately 57% of all US equipment installs are ultimately returned to Xerox for end-of-life disposal, a figure that rises to 100% for leased equipment.[295]

Assuming that lease and rental are likely only to apply to a small proportion of B2C equipment – i.e., the more expensive items and those that get rarely used by consumers, and for those

[295] Xerox (2018) 2018 Corporate Social Responsibility Report. Available at: link

products at technological maturity, and to some categories of B2B equipment, the maximum level of efficiency was initially estimated at between 20% to 40% with red RAG evidence rating.

In the workshop, ten of the seventeen stakeholders voted on the maximum level of efficiency – consisting of three academics, two thinktanks, one social enterprise, one NGO, one producer compliance scheme, one manufacturer and one trade body. There was therefore good representation from the EEE sector. Of the ten stakeholders that voted, two voted for a maximum level of efficiency of 20-30%, one with medium confidence and another without a confidence level. One stakeholder remarked that this level could only be achieved if a pollution tax applied to the cheap, low-quality products that flood the market, effectively raising their price and making sharing or renting the cheapest option.

Three stakeholders voted for a maximum level of efficiency of 30-40%, one with medium confidence and two with low confidence. The remaining five stakeholders voted with “Don’t Know”. Of the stakeholders that voted “Don’t Know”, one stakeholder remarked that a maximum level of efficiency was difficult to quantify, since informal sharing activities (for example, sharing an infrequently used item such as a drill or hedge trimmer with a neighbour) cannot be measured in a robust way. Measuring commercial activities (for example rental or lease of televisions or washing machines), on the other hand, could be more feasible.

Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency for Measure 6 is 20-40%. A reasonable consensus on a narrower range for the maximum level of efficiency was not agreed during the workshop. As such, the RAG evidence rating remains red to indicate the uncertainty and low levels of confidence in this range.

6.4.3 Business-as-usual in 2035

There was no quantitative data found in the literature that indicated what the business-as-usual level of efficiency would be for these types of circular economy businesses models. However, one survey that was conducted on university students indicated that 56% of those surveyed would be interested in rental, repair and maintenance services for electronic goods throughout the year.[296] This demonstrates that there is the potential for increase if the industry made the option available, but it is not possible to extract the interest solely in leasing. This would mainly be for IT equipment, similar to the use that is already observed by some businesses.

Similarly, stakeholder interviews did not result in any quantitative data for the business-as-usual scenario. Some highlighted that there is potential for the sector to grow, particularly in B2B, and where the technology has plateaued, with stakeholder indicating that major domestic appliances had the most potential to increase. One stakeholder suggested that encouragement or enforcement of retailers, such as B&Q, to offer rental services would increase uptake, but the current level of action from retailers is limited. However, another stakeholder suggested that the cost of rental services and the availability and ease of purchasing new, cheap products will mean that the rental industry will struggle to become the economically preferred option.

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[296] Students Organising for Sustainability (2019) Student Opinion: Reuse and rental of electronic equipment. Available at: link

Similarly, another stakeholder explained that there has not been the uptake and interest observed from consumers when manufacturers have offered rental and leasing services.

Therefore, it was initially estimated, with an amber RAG evidence rating, that the business-as-usual scenario would be between 5% to 20%.

In the workshop, eight of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of three academics, one thinktanks, one social enterprise, one producer compliance scheme, one manufacturer and one trade body. There was therefore good representation from the EEE sector. Of the eight stakeholders that voted, six voted for a business-as-usual level of efficiency of 5% to 10%, all with a low confidence level. One stakeholder voted for a business-as-usual level of efficiency of 11% to 20% with medium confidence. The remaining stakeholder voted “Don’t Know” but remarked that the level is likely to be higher but hard to quantify. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the business-as-usual level of efficiency for Measure 6 is 5% to 20%. A reasonable consensus on a narrower range for the business-as-usual level of efficiency was not agreed during the workshop, since many of the stakeholders voted with low confidence. As such, the RAG evidence rating has been reduced from amber to red to indicate the uncertainty and low levels of confidence in this range.

7.0 Measure 7 – Direct Reuse

7.1 Electricals resource efficiency measure

7.1.1 Description

The direct reuse of used (commonly referred to as "second-hand") EEE, without the need of repair or refurbishment. This is sold or donated used EEE for reuse. This can avoid the consumption of new EEE and increase a functional EEE product's lifespan.

A large number of used EEE are disposed or recycled while they are still functioning, meaning they are not available for reuse. For instance, one study assessed the reusability of used EEE disposed of at five Household Waste and Recycling Centres (HWRCs) in England. Over 100 of the used EEE were PAT tested and categorised based on their condition. 26% of large used EEE and 4% of small used EEE were found to be fully functional and reusable. Extrapolating these findings across the UK, it was estimated that 17,000 tonnes of functioning EEE (without the need for repair), worth an estimated £17.8M, was disposed of at HWRCs per year.[297] As such, the reuse market has the potential to minimise WEEE generation by redirecting functional used EEE back into use. This can reduce resource consumption, and its associated greenhouse gas emissions, by displacing the consumption of new EEE products. This approach follows the Waste Hierarchy, in which the reuse of functioning products is preferred over recycling (see Measure 9). In instances where used EEE is damaged and not suitable for reuse, other options such as repair, refurbishment, or recycling may be required.

7.1.2 Measure indicator

The indicator that was selected was the **percentage of used EEE products that are reused**. The reuse of used EEE represents the avoided consumption of new EEE and, therefore, avoided resource use and its associated greenhouse gas emissions. However, it is recognised that the purchase of one used EEE product may not necessarily displace the purchase of one new EEE product – i.e., it is unlikely there will be a 1:1 displacement rate. This can be for many reasons, such as: the lifespan of used EEE may be lower than that of new EEE, so the used EEE may be replaced sooner; a consumer may only purchase used EEE, so would not have purchased the EEE as new; or a consumer may continue to purchase new EEE along with the reused EEE. However, no evidence was identified from the EEE sector suggesting a more realistic displacement rate. As such, the assumption is that the purchase of one used EEE product will avoid the purchase of one new EEE product – i.e., a 1:1 displacement rate. It is worth noting, though, that different displacement rates (or "replacement rates") are known for the clothing reuse sector. For example, it has been reported that, on average, the purchase of 2.56 used clothing items avoids the purchase of one new clothing item – i.e., a 1:2.56 displacement rate. One possible reason for this is that consumers may still buy the used clothing item due to emotion (i.e., "want") rather than utility (i.e., "need"), so purchasing a used

[297] WRAP (2011) Realising the Reuse Value of Household WEEE. Available at: link

product does not displace a new product.[298] Consumer behaviour surrounding EEE reuse will likely differ to that of clothing reuse (e.g., fashion and use). Therefore, a 1:1 displacement rate for reused EEE is assumed.

7.1.3 Examples in practice

The reuse sector (including EEE reuse) in the UK is well established, with resale platforms for multiple sales channels. Examples of reuse platforms are extensive, which include: [299]

- Peer-to-peer, such as at car-boot sales, on noticeboards, and on digital platforms such as eBay, Facebook Marketplace, and Gumtree.
- Business-to-consumer, such as customer returns and take-back schemes, with OEMs and retailers then selling the used EEE at a reduced price to consumers.
- Business-to-consumer, such as third-party businesses who are specifically set up as a reuse organisation, such as CEX, Cash Converters, and digital platforms such as Back Market and Music Magpie.
- Business-to-consumer, such as charities and social enterprises including DEBRA UK, the British Heart Foundation, and the Stirling Reuse Hub who sell donated used EEE to consumers.
- Business-to-business, such as third-party businesses directing used EEE from one business to another and businesses selling or donating their used EEE directly to charities and social enterprises.

7.2 Available sources

7.2.1 Literature review

The literature review identified twenty-six sources that discussed the reuse of used EEE as a resource efficiency measure. These comprised:

- Eleven academic papers;
- Eight technical studies;
- Five website articles;
- One policy document; and
- One industry report.

The relevant sources were considered of high applicability and credibility, when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.4, with twenty-one sources exhibiting an IAS of 4 or above. Fourteen sources were specific to the UK.

[298] Vaayu (2021) Vinted Climate Change Impact Report 2021. Available at: link
[299] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link

Two sources had publication dates of over ten years old. Because of this, a balanced approach was taken, considering the literature, stakeholder interview insights and workshop findings.

7.2.2 Interviews

In the stakeholder interviews, eleven stakeholders commented on the reuse of used EEE. There was consensus that the reuse of used EEE is well established in the UK, with informal reuse (i.e., peer-to-peer) being well known and commonly used. Consumer demand for sustainable products was considered a driver for uptake of used EEE, as reuse generally represents lower environmental impacts than new EEE due to the avoided manufacturing activities and resources used. Stakeholders also agreed that used EEE is generally less expensive to purchase than new EEE but offers largely the same functionality as new EEE. Most stakeholders also believed that reuse organisations improve consumer confidence in used EEE, since testing and quality checks are regularly carried out.

As for barriers, there was overall agreement that informal reuse might not be trusted by some consumers due to safety, data security, and lifespan concerns. Additionally, indefinite storage of used EEE by consumers was highlighted as a barrier to the availability of used EEE for reuse. Technological obsolescence (i.e., hardware or software becoming outdated) was another barrier highlighted by stakeholders, since outdated used EEE may not be fully functional. Similarly, older used EEE could be regarded as unfashionable, with negative consumer perceptions of used EEE being a commonly stated barrier. Finally, some stakeholders explained that large used EEE (such as fridges and washing machines) may be difficult to transport, posing a barrier for the distribution of used EEE for reuse.

Overall, stakeholders felt that the reuse of used EEE is well established in the UK, with cost and demand for sustainable products posing key drivers to its uptake. However, there are barriers largely surrounding availability and negative consumer perceptions of used EEE, which may limit uptake.

7.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 7. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academia, social enterprises, thinktanks, trade bodies, an NGO, a producer compliance scheme and a manufacturer. The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current level of efficiency, but some explained that the level of reuse would vary depending on the type of used EEE. As for the business-as-usual and maximum levels of efficiency, the majority of stakeholders that voted believed that the levels would be higher than proposed. However, no quantified levels were provided. One stakeholder added that there was a trend for local authorities to raise awareness of reuse, which could drive an increase the reuse of used EEE. Whilst there was potential to increase the reuse rate of used EEE, several stakeholders explained that used EEE would need to be stored and handled carefully. This would ensure the used EEE could be reused without the need for repair. One stakeholder from a social enterprise added that used EEE stored outside can result in water damage, with another stakeholder from a manufacturer adding that used

EEE can be handled in a way that damages the product if it is not perceived to be of high value.

The level of engagement in the workshop was as follows:

- Eleven stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Four stakeholders actively contributed to verbal discussion, with five stakeholders contributing on the Teams chat.

7.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

7.3.1 Drivers

Table 21 below shows the main drivers for Measure 7. The most substantial drivers are shown in bold as voted for by stakeholders in the workshop.

Table 21: Drivers for EEE Measure 7

Description	PESTLE	COM-B
Used EEE is generally less expensive to purchase than new EEE.[300] [301] [302] Some returned EEE may also be directed to charities free-of-charge or at a reduced rate.	**Economic**	**Motivation – automatic**
Used EEE can have the same functionality as new EEE.[303]	**Technological**	**Capability – physical**
Consumer demand for sustainable products and acceptance of used products. [304] [305]	**Social**	**Motivation – automatic**

300 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
301 Stakeholder interview
302 Cole et al. (2017) Towards a circular economy: exploring routes to reuse for discarded electrical and electronic equipment. Available at: link
303 Stakeholder interviews
304 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
305 Stakeholder interviews

Description	PESTLE	COM-B
EEE can be designed for reuse, whereby the durability and lifespan of the product is factored in at the design stage. This may include the use of more durable materials. [306]	**Technological**	**Capability – physical**
Consumers may perceive older EEE to be higher quality than new EEE.[307]	Technological	Motivation – automatic
Economic incentive for individuals and organisations to sell used EEE – either to make money as an individual or as a business model.[308] [309] [310] [311]	Economic	Motivation – automatic

Used EEE is generally less expensive to purchase than new EEE

A major driver for the uptake of used EEE is that used EEE can be purchased at a lower cost than new EEE. This allows access to EEE for consumers who may be unable to afford new EEE. In some situations, retailers and manufacturers also donate (or sell at a low cost) used EEE to charities and social enterprises. In the workshop, seven of the twenty-three votes for the top three drivers were for this driver. This was the joint highest voted driver amongst workshop stakeholders.

Used EEE can have the same functionality as new EEE

Although new EEE placed on the market may have improved features (such as a higher resolution camera, a bigger screen, or more 'smart' elements), many of these additional features do not impact the core functionality of the product. For example, new features such as a touchscreen on a laptop or an LED display on a washing machine are not absolutely necessary for many consumers. Therefore, a lower cost, lower specification item with essentially the same functionality, makes used EEE an attractive alternative to new EEE. As such, similar functionality for used EEE, combined with a lower purchase cost, acts as a driver for used EEE. In the workshop, seven of the twenty-three votes for the top three drivers were for this driver. This was the joint highest voted driver amongst workshop stakeholders.

[306] Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
[307] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[308] George, S. (2023) Second-Hand Tech: Could 2023 Be A Tipping Point for E-Waste? Available at: link
[309] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link
[310] Stakeholder interviews
[311] Cole et al. (2017) Towards a circular economy: exploring routes to reuse for discarded electrical and electronic equipment. Available at: link

Consumer demand for sustainable products and acceptance of used products

Consumer demand for sustainable products, such as reused EEE, can increase the reuse rate of used EEE. This can be based on increased consumer awareness of climate change and the reduced greenhouse gas emissions related to reuse compared with new products. Additionally, consumer acceptance of used products can further increase the demand for reusing used EEE. In the workshop, four of the twenty-three votes for the top three drivers were for this driver. This was the third highest voted driver amongst workshop stakeholders.

EEE can be designed for reuse

Another major driver for the uptake of used EEE is that EEE can be designed for reuse, whereby the durability and lifespan of the product is factored in at the design stage (e.g., the use of durable materials, waterproof and dustproof components and use of components which do not outdate). In doing so, the lifespan of EEE can be extended, increasing the chance of used EEE being reused several times. In the workshop, five of the twenty-three votes for the top three drivers were for this driver. This was the second highest voted driver amongst workshop stakeholders.

7.3.2 Barriers

Table 22 below shows the main barriers for Measure 7. The most substantial barriers are shown in bold as voted for by stakeholders in the workshop.

Table 22: Barriers for EEE Measure 7

Description	PESTLE	COM-B
Indefinite storage of used EEE by consumers, making them unavailable for reuse.[312] [313] [314] [315] [316]	**Social**	**Opportunity – social**
Consumer preference for new EEE and negative perceptions of used	**Social**	**Motivation – automatic**

[312] Green Alliance (2015) A circular economy for smart devices. Available at: link
[313] Stakeholder interviews
[314] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link
[315] Material Focus (2023) 7.5 million unused electrical toys gathering dust in UK homes. Available at: link
[316] Material Focus (2022) 39 million tech items are hoarded in UK homes including £1.5 billion worth of working laptops that could be resold. Available at: link

Description	PESTLE	COM-B
EEE (e.g., "not in fashion").[317] [318] [319] [320]		
Lack of (or reduced) warranty for used EEE may be perceived by consumers as having low durability or a short lifespan.[321] [322] [323]	**Technological**	**Motivation – automatic**
Used EEE may have shorter or unknown lifespans compared with new EEE.[324] [325]	**Technological**	**Capability – physical**
Consumers may be concerned about the safety of used EEE, particularly from peer-to-peer sales. For example, fire risks and hygiene. [326] [327] [328]	**Technological**	**Motivation – automatic**
Consumers may be concerned about data privacy and security when donating, selling, or purchasing used EEE.[329] **This may also result in indefinite storage of used EEE by**	Technological	Motivation – automatic

[317] Bovea et al. (2018) A survey on consumers' attitude towards storing and end-of-life strategies of small information and communication technology devices in Spain. Available at: link
[318] Stakeholder interviews
[319] Cole et al. (2017) Towards a circular economy: exploring routes to reuse for discarded electrical and electronic equipment. Available at: link
[320] CEPS (2019) Identifying the impact of the circular economy on the Fast-Moving Consumer Goods Industry: Opportunities and challenges for businesses, workers and consumers – mobile phones as an example. Available at: link
[321] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[322] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[323] CEPS (2019) Identifying the impact of the circular economy on the Fast-Moving Consumer Goods Industry: Opportunities and challenges for businesses, workers and consumers – mobile phones as an example. Available at: link
[324] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[325] Stakeholder interviews
[326] Bovea et al. (2017) Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. Available at: link
[327] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[328] Stakeholder interviews
[329] Stakeholder interviews

Description	PESTLE	COM-B
consumers or being destroyed and disposed. [330]		
Inconvenience of purchasing and selling used EEE.[331] [332] This may be especially relevant for large used EEE that could take up space and be difficult to handle and transport.	Social	Capability – psychological
Minor cosmetic imperfections lower the chances of resale, even if the used EEE is fully functional.[333] [334]	Social	Motivation – automatic
Lack of incentives for producers to increase the durability and lifespan of EEE, which is required for effective reuse.[335]	Legal	Motivation – automatic
Lack of interoperability between hardware and new software, making EEE quickly outdated and potentially obsolete.[336] [337] [338]	Technological	Capability – physical
Some used EEE may cost more to operate than new EEE based on efficiency ratings, resulting in a higher overall cost to the consumer.[339]	Economic	Capability – physical

[330] CEPS (2019) Identifying the impact of the circular economy on the Fast-Moving Consumer Goods Industry: Opportunities and challenges for businesses, workers and consumers – mobile phones as an example. Available at: link
[331] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[332] Stakeholder interviews
[333] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[334] Stakeholder interviews
[335] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[336] Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
[337] Stakeholder interviews
[338]
CEPS (2019). Identifying the impact of the circular economy on the Fast-Moving Consumer Goods Industry: Opportunities and challenges for businesses, workers and consumers – mobile phones as an example. Available at: link
[339] Hischier and Böni (2021) Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study. Available at: link

Description	PESTLE	COM-B
Producers and OEMs may be reluctant to sell used EEE at a lower price than new EEE equivalents, as it may undermine sales of new EEE.[340]	Economic	Motivation – automatic
Consumers may lack awareness of reuse opportunities, such as selling or donating, resulting in disposal or recycling of functional used EEE.[341] [342] [343]	Social	Capability – psychological
There may be a limited price difference between new and used EEE. As such, some consumers may be willing to pay more for new EEE.[344] [345]	Economic	Capability – physical
Used EEE may be stored, handled, and/or transported in a way that causes damage to its aesthetics (e.g., dents or scratches) or functionality (e.g., water damage or broken screen). [346]	Technological	Capability – physical
Limited range of used EEE available to consumers compared with new EEE.[347]	Social	Motivation – reflective
A lack of quality standards for used EEE limits consumer confidence in used EEE.[348]	Technological	Capability – physical
Lacking existing circular logistics that enable the collection, cleaning and redistribution of used EEE.[349]	Social	Capability – physical

340 Stakeholder interviews
341 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
342 Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
343 Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link
344 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
345 Stakeholder interviews
346 WRAP (2011) Realising the Reuse Value of Household WEEE. Available at: link
347 Stakeholder interviews
348 Stakeholder interviews
349 Green Alliance (2023) Ready steady grow: how the Treasury can mainstream circular business. Available at: link

Description	PESTLE	COM-B
Less focus on used EEE reuse due to emphasis on WEEE recycling targets. [350]	Political	Capability – physical

Indefinite storage of used EEE by consumers

A major barrier to the reuse of EEE is the indefinite storage of used EEE by consumers in their homes. Used EEE might be kept as a spare ("just in case"), for sentimental reasons, due to data privacy concerns, or due to uncertainty or inconvenience of selling or donating the item. This prevents functional used EEE from being reused. Notably, it has been estimated that 20.7 million functional used EEE items are stored indefinitely by consumers in UK households, worth a possible £5.63 billion – the equivalent of about £200 per household. The majority of these items are believed to be IT products, such as smart phones, laptops and tablets.[351] Similarly, it has been estimated that 7.5 million electrical children's toys are indefinitely stored by consumers in UK households, with 72% believed to be functional.[352] Where used EEE are stored for long periods of time, the value and functionality of the items can reduce, meaning the potential for reuse diminishes – such as battery degradation and software and hardware becoming obsolete. As such, ensuring used EEE are donated or sold for reuse is important for maximising resource efficiency. In the workshop, four of the twenty-six votes for the top three barriers were for this barrier. This was the joint highest voted barrier amongst workshop stakeholders.

Lack of consumer awareness, acceptance, and convenience

Another major barrier to EEE reuse is the lack of consumer awareness of routes for donation of used EEE, concerns over data security, and the convenience of residual WEEE disposal over donation for reuse.

Consumers may dispose of functioning used EEE that could be directed to the reuse market. A large number of functional used EEE are disposed of in residual waste, with sources ranging from 5% to 17% in the UK and other high-income countries. This range depends on the EEE category, with small household appliances being at the top end of the range, as they tend to be small enough to fit inside residual waste bins.[353] Another source investigated electrical toys in Spain and found that 67.1% of consumers disposed of electrical toys via residual waste.[354] As such, a lack of consumer awareness (possibly combined with convenience of disposing used EEE instead of selling or donating) may be a cause of the improper management of functional used EEE. Stakeholders also indicated that there was a lack of consumer awareness

[350] Stakeholder input from workshop
[351] Material Focus (2022) 39 million tech items are hoarded in UK homes including £1.5 billion worth of working laptops that could be resold. Available at: link
[352] Material Focus (2023) 7.5 million unused electrical toys gathering dust in UK homes. Available at: link
[353] Cole et al. (2017) Towards a circular economy: exploring routes to reuse for discarded electrical and electronic equipment. Available at: link
[355] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link

surrounding where reputable used EEE could be purchased. They also indicated that additional effort may be required to source a specific used EEE product, which may be considered inconvenient. As such, a lack of consumer awareness and convenience of directing functional used EEE for reuse, combined with negative perceptions of used EEE, may pose a barrier to the availability and uptake of used EEE reuse. In the workshop, two of the twenty-six votes for the top three barriers were for consumer preference for new EEE and negative perceptions of used EEE. Additionally, inconvenience of purchasing and selling used EEE was voted by one of the twenty-six workshop stakeholders as a key barrier.

Consumer concerns and perceptions on lack of warranty, data privacy and safety

Another barrier is negative consumer perceptions towards used EEE, surrounding safety, and product lifespan. Additionally, some consumers may perceive used EEE as being “outdated” and “unfashionable” if newer versions are available – similar to clothing fashion.[355]

Limited or even no safety testing may be conducted when certain reuse routes are used, particularly peer-to-peer. This may be less of a concern when purchasing used EEE from licensed reuse organisations, who often perform safety and quality checks on the items before selling them. Similarly, there may be consumer concerns surrounding used EEE lifetimes and lack of warranties, which would otherwise provide reassurance to consumers.[356] Again, this is further exacerbated by peer-to-peer sales routes, as there is often no approved guarantee of the used EEE’s condition.

Finally, minor cosmetic imperfections can render the used EEE undesirable, despite the item being fully functional. These concerns and negative perceptions by some consumers may limit the uptake of used EEE for reuse. In the workshop, four of the twenty-six votes for the top three barriers were for the lack of warranty for used EEE. This was the joint highest voted barrier amongst workshop stakeholders. Additionally, three of the twenty-six votes were for used EEE possibly having shorter or unknown lifespans compared with new EEE. Furthermore, three of the twenty-six votes were for consumer concerns about data privacy and security associated with selling, donating or purchasing used EEE. A further two of the twenty-six votes were for consumer concerns about the safety of used EEE, such as fire risks and hygiene. As such, consumer concerns and perceptions of used EEE were identified barriers from workshop stakeholders.

[355] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
[356] Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link

7.4 Levels of efficiency

Table 23: Levels of efficiency for EEE Measure 7

Indicator: % of used EEE products that are reused			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	15%	30%	20%
Evidence RAG	Green	Amber	Red

7.4.1 Current level of efficiency

Quantitative and qualitative data was identified in the literature surrounding used EEE reuse, including tonnage data and consumer behaviour.

The reuse rates for mobile phones are commonly quoted in tandem with refurbishment rates (see Measure 5). For example, one source stated that 11% of the global smartphone market is made up of refurbished and used smartphones,[357] which reduces slightly to 10% for the European market.[358] Both of the sources exhibit an IAS of 4. Similarly, in the UK, one source stated that 9% of consumers have purchased a refurbished or used EEE smartphone, with this source also exhibiting an IAS of 4.[359] However, the common grouping of refurbishment and reuse makes it difficult to extract reuse rates.

For small personal EEE, such as cameras, mobile phones, tablets, and laptops, one source indicated that 87.65% of consumers had never purchased these products used.[360] This source exhibits an IAS of 5 and is in reference to the Spanish market, so can be applied to the UK.

As for household appliances, one study found that 0.75% of consumers to state that they had purchased used small household EEE.[361] This source exhibits an IAS of 5 and is in reference to the Spanish market, so can be applied to the UK. Another study, based in the UK with an IAS of 4, found AATFs to report 5% of displays, 2.44% of cooling equipment, 0.59% of large household appliances, and 0.49% of small mixed WEEE are diverted for reuse.[362] However, figures reported by AATFs only represents used EEE sent to AATFs, so does not represent

357 Assurant (2021) Growth of Interest for Refurbished Devices. Available at: link
358 Gillet and Pratty (2022) Money for old phones — but can the refurb boom last? Available at: link
359 Assurant (2021) Growth of Interest for Refurbished Devices. Available at: link
360 Bovea et al. (2018) A survey on consumers' attitude towards storing and end-of-life strategies of small information and communication technology devices in Spain. Available at: link
361 Perez-Belis et al. (2017) Consumer attitude towards the repair and the second-hand purchase of small household electrical and electronic equipment. A Spanish case study. Available at: link
362 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link

peer-to-peer, B2B, or B2C reuse that is. Therefore, these figures from AATFs are deemed too low to use for the current level of efficiency.

With reference to commercial B2B reuse, one study focusing on the UK market, with an IAS of 5, stated that the reuse of commercial IT equipment, is more common and is likely to be high. However, this study could not provide a rate of reuse due to a lack of data.[363] This equipment is mostly managed through IT Asset Disposition (ITAD) companies, who specialise in disposing redundant or unwanted IT equipment. However, not all ITADs are signed up to the Asset Disposal and Information Security Alliance (ADISA) industry standards, so some disposal may be carried out by companies with lower standards (colloquially known as 'jobbers'). B2B WEEE in scrap metal is estimated to include tens of thousands of tonnes of professional equipment.[364]

Sources also provided survey data, with one stating that only 6% of surveyed Europeans had bought used EEE, with 40% claiming they would consider purchasing used EEE.[365] Finally, a comprehensive study conducted in Romania, with an IAS of 5, found that 25.11% of consumers reported diverting used EEE for reuse, which included selling or donating to another person. However, only 15.64% of consumers reported purchasing used EEE.[366] As discussed previously, this source is relevant to the Romanian market, which may exhibit higher levels of reuse than the UK market due to lower incomes in Romania.

Stakeholder interviews confirmed that there is an established market for used EEE reuse, including peer-to-peer and B2C sales routes. This includes large domestic appliances, whereby one stakeholder indicated that this market was already well established and commonly used. Stakeholders also raised that peer-to-peer reuse is common, with functional used EEE also being passed on between family members.

In terms of overall EEE reuse rates in the UK, the most reliable study identified was one assessing EEE and WEEE flows for 2020, with an IAS of 5. This study estimated a wide range of B2B and B2C WEEE and EEE flows. The study reported 82,000 tonnes of used domestic EEE processed by reuse organisations, with a further 90,000 tonnes of used commercial EEE processed by reuse organisations. An additional 90,000 tonnes of used EEE was processed by ITADs, of which over 80% would likely be fit for reuse. A further 102,000 tonnes of used EEE was warranty returns, of which 50% (based on previous projects) was reused. This study, combined with industry experience, therefore indicated that EEE reuse in the UK is likely to be around 17% (295,000 tonnes of used EEE reused from 1,774,000 tonnes used EEE).[367] Another source, with an IAS of 5, indicated that a maximum of 12% of used EEE is reused in the UK.[368] Therefore, a current level of efficiency of 15% for EEE reuse was initially estimated,

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363 Material Focus (2022) Business Electrical Waste: Challenges and Opportunities. Available at: link
364 Material Focus (2022) Business Electrical Waste: Challenges and Opportunities. Available at: link
365 Parajuly et al. (2020) Behavioral change for the circular economy: A review with focus on electronic waste management in the EU. Available at: link
366 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link
367 Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link
368 WRAP (2017) Switched on to value: powering business change. Available at: link

with an amber RAG evidence rating. As mentioned previously, this level of efficiency represents avoided consumption of new EEE, with an assumed displacement rate of 1:1 (i.e., one reused EEE product avoids the use of one new EEE product).

In the workshop, seven of the seventeen stakeholders voted on the current level of efficiency – consisting of two academics, one social enterprise, one producer compliance scheme, one manufacturer, one NGO and one trade body. There was therefore good representation from the EEE sector. Of the seven stakeholders that voted, six voted for a current level of efficiency of 15%, all indicating medium confidence. The other remaining vote was from an NGO, who voted for a current level of efficiency greater than 15%. They explained that it could be above 20%, since local authorities are raising more public awareness of reuse. The NGO added that from waste compositional analysis, they found 35% of WEEE going to recycling was not broken, indicating it may be suitable for reuse.

Another stakeholder (a producer compliance scheme) explained that informal reuse of used EEE was common for certain EEE products, such as cookers and large domestic appliances, whereas small domestic appliances tend to be more personal and so may less likely be reused. They agreed that the overall current level of efficiency of 15% seemed reasonable. An NGO and thinktank added that small domestic appliances are often relatively cheap to buy new, and so the economics of purchasing used may not be as attractive. Overall, stakeholders tended to agree with the current level of efficiency being 15%. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 7 is 15%, with a green RAG evidence rating. This increase from amber to green RAG evidence rating is based on consensus from stakeholders at the workshop, all with medium confidence.

7.4.2 Maximum level of efficiency in 2035

The maximum level of efficiency for EEE reuse is heavily dependent on the condition of used EEE when they are diverted for reuse. A number of studies in the literature focussed on the condition of used EEE for direct reuse without the need for repair. The literature presented a range of figures based on different EEE categories.

One study, with an IAS of 5, looked at a sample of small household appliances in Spain. Only 2.1% of used EEE was suitable for direct reuse with only minor cleaning operations required. 30.2% of used EEE was deemed unsuitable for reuse, even when repair was factored in.[369] Another study, based in Denmark with an IAS of 5, reported that 22% of used EEE collected for reuse was in suitable condition for direct reuse.[370] Similarly, a study in Spain, with an IAS of 5, suggested that 20-30% of discarded used EEE was in suitable condition for direct reuse.[371] A study based in the UK, with an IAS of 5, assessed the condition of used EEE disposed of at five HWRCs. The researchers spoke with 585 members of the public who were disposing of

[369] Bovea et al. (2016) Potential reuse of small household waste electrical and electronic equipment: Methodology and case study. Available at: link
[370] Parajuly et al. (2020) Behavioral change for the circular economy: A review with focus on electronic waste management in the EU. Available at: link
[371] Bovea et al. (2016) Potential reuse of small household waste electrical and electronic equipment: Methodology and case study. Available at: link

their used or waste EEE at the HWRCs. 30.3% of those interviewed believed their used EEE was suitable for direct reuse, without the need for repair. However, when assessing the used EEE, 26% of large used EEE and 4% of small used EEE were found to be suitable for direct reuse without the need for repair. The overall potential for direct reuse was 12% by number or 19% by weight. A possible reason for this difference in interview responses and assessed used EEE may be that 55% of those interviewed said they left their used EEE outside before taking it to the HWRC. This would likely damage and degrade the used EEE.[372] A similar UK study, also with an IAS of 5, found that 17% of discarded microwaves were suitable for direct reuse without the need of repair.[373] A final UK study, with an IAS of 4, suggested that 40% of disposed washing machines, fridges, televisions, laptops, and vacuum cleaners were suitable for direct reuse. It added that, for washing machines, 80% had the potential for reuse with repair, highlighting the interdependency between the Measure 7 and Measure 5.[374]

One stakeholder in the interviews highlighted that it would not be unrealistic for used EEE sales to occupy 30-40% of EEE sales. However, it is possible that this figure includes EEE that have undergone some form of repair or refurbishment. Others indicated that the maximum reuse rate by 2035 could reach 70%.

On balance, it was initially estimated that the maximum level of efficiency for direct reuse of used EEE would be 30%, with a green RAG evidence rating. As mentioned previously, this level of efficiency represents avoided consumption of new EEE, with an assumed displacement rate of 1:1 (i.e., one reused EEE product avoids the use of one new EEE product).

In the workshop, nine of the seventeen stakeholders voted on the maximum level of efficiency – consisting of two academics, two thinktanks, two social enterprises, one producer compliance scheme, one manufacturer and one NGO. There was therefore good representation from the EEE sector. Of the nine stakeholders that voted, five voted for a maximum level of efficiency of above 30%, all indicating medium confidence. However, none of the stakeholders quantified this. The four remaining votes were for “Don’t’ Know”, with one stakeholder adding that the maximum level of efficiency would largely be driven by consumers as opposed to regulation. Overall, stakeholders tended to believe that the maximum level of efficiency would be greater than 30%. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency for Measure 7 is set at 30% by 2035, with an amber RAG evidence rating. This change from a green to an amber RAG evidence rating is due to uncertainty as to what extent the maximum level of efficiency may be greater than 30%, which was indicated in the workshop.

7.4.3 Business-as-usual in 2035

There was a lack of quantitative and qualitative information provided in the literature for the business-as-usual level of efficiency by 2035 for this Measure. One source, with an IAS of 4,

[372] WRAP (2011) Realising the Reuse Value of Household WEEE. Available at: link
[373] Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
[374] DSS (2022) The eco-modulation of producers’ financial obligations for WEEE in the UK. Available at: link

stated that 25% of students in the UK expressed an interest in buying used EEE.[375] This suggests consumer perception towards used EEE is improving, and that consumers are potentially becoming more accepting of used products. However, this figure may only be relevant to students, who tend to have limited disposable income. There was insufficient data in the literature or gathered through the stakeholder interviews to confirm this figure. Stakeholders indicated that the business-as-usual level of efficiency had the potential to increase towards the maximum level of efficiency (i.e., 30%) by 2035.

The lack of warranties provided via certain reuse routes, such as peer-to-peer, may limit the uptake of used EEE. However, if formal reuse channels continue to develop, and if the issues surrounding warranties and consumer concerns over lifetime are mitigated, there is the potential for consumer perception towards used EEE to further improve. It was therefore initially estimated, with a red RAG evidence rating, that the business-as-usual level of efficiency would be 20% by 2035. As mentioned previously, this level of efficiency represents avoided consumption of new EEE, with an assumed displacement rate of 1:1 (i.e., one reused EEE product avoids the use of one new EEE product).

In the workshop, eight of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of two academics, two social enterprises, one manufacturer, one NGO, one thinktank and one trade body. There was therefore good representation from the EEE sector. Of the eight stakeholders that voted, seven voted for a business-as-usual level of efficiency of above 20%, all indicating medium confidence. However, none of the stakeholders quantified this. One social enterprise stakeholder mentioned that reuse targets and investment in reuse systems would be key to increasing the amount of used EEE being reused, suggesting the level of efficiency would be above 20%. The one remaining vote was for “Don’t Know”. Overall, stakeholders tended to believe that the business-as-usual level of efficiency would be greater than 20%. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the business-as-usual level of efficiency for Measure 7 is 20%, with a red RAG evidence rating. The continued red RAG evidence rating is due to uncertainty as to what extent the business-as-usual level of efficiency may be greater than 20%, which was indicated in the workshop.

[375] Students Organising for Sustainability (2019) Student Opinion: Reuse and rental of electronic equipment. Available at: link

8.0 Measure 8 – Remanufacture

8.1 Electricals resource efficiency measure

8.1.1 Description

Remanufacturing returns a product to a like-new condition. In order to classify EEE as being "remanufactured", the product must be brought to the OEM's original performance specifications and be given an equal warranty to that of an equivalent new product.

The term "remanufacture" is sometimes used interchangeably with the terms "repair" and "refurbish" (Measure 5). However, where refurbished or repaired EEE extends the products lifespan but is generally not given a full "like new" warranty; remanufactured EEE is fully restored to a "like new" status (or better) and is given a full "like new" warranty. Remanufacturing EEE involves disassembly, along with the inspection, cleaning and testing of its components, in line with specific technical specifications and standards. The product is then reassembled using reused, repaired and/or new replacement parts, where required. Consequently, the remanufactured EEE should look and function the same (or better) as new EEE, whilst generally costing less to purchase than new EEE. A full warranty should also be provided for remanufactured EEE, equal to that of an equivalent new EEE.[376] [377] [378]

Remanufacture is largely reliant on the design of EEE, namely the ease of disassembly and the compatibility, availability and durability of used or new spare parts. Furthermore, there must be consumer demand for remanufactured EEE. Regardless, remanufactured EEE offers the potential to avoid the consumption of new EEE, reducing resource consumption and associated greenhouse gas emissions.

8.1.2 Measure indicator

The indicator that was selected was the **percentage of EEE that is remanufactured for reuse**. The reuse of parts results in resource, energy and associated greenhouse gas emission savings compared to the manufacture of new EEE. Since the used EEE is restored to a "like new" status, with reassurance of being given a "like new" full warranty, the assumption here is that one remanufactured EEE product will displace the consumption of one new EEE product – i.e., a 1:1 displacement rate. However, it is recognised that new replacement parts may be required for the remanufacture of EEE (such as new batteries),[379] which will need to be considered during the modelling of the reduced raw material consumption and greenhouse gas emissions.

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[376] Zlamparet et al. (2017) Remanufacturing strategies: A solution for WEEE problem. Available at: link
[377] IRP (2018) Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. A Report of the International Resource Panel. Available at: link
[378] Yuksek et al. (2023) Sustainability Assessment of Electronic Waste Remanufacturing: The Case of Laptop. Available at: link
[379] IRP (2018) Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. A Report of the International Resource Panel. Available at: link

8.1.3 Examples in practice

Remanufacturing is mostly carried out by OEMs but can also be carried out by sub-contractors and independent third parties, depending on the availability and feedstock of replacement parts. There are examples of businesses that currently offer remanufactured EEE to consumers as part of their product range:

- The printer company, Xerox, has an established remanufacturing process of commercial printing and scanning equipment. Products are designed with a high level of cross-compatibility of parts. Xerox claim to reuse 70-90% of components (by weight) without degradation of quality or performance. Around half of Xerox printing devices returned in the USA are directly reused or are sent for remanufacture.[380]
- The domestic appliances company, Whirlpool, operates its “Reworks” appliance remanufacturing facility in Peterborough, England. There are three sales outlets in England, offering a range of remanufactured appliances – such as ovens, fridges, dishwashers and microwaves. There are two grades of remanufactured products – one being damaged during manufacture or transit and the other being faulty or damaged products returned by retailers. All products, including Indesit, Hotpoint, KitchenAid and Whirlpool are given a full manufacturers’ guarantee, with the purchase cost being less compared to the equivalent new products.[381]
- The photography and printing equipment company, Canon, offers a range of remanufactured multifunctional devices (i.e., commercial printers and scanners) – referred to as the “imageRUNNER ADVANCE ES” range. All products suitable for remanufacture are sent to a centralised facility in Germany, where the products are inspected, disassembled and the parts are cleaned, repaired and/or replaced, if required. The products are then reassembled, with the entire process following the remanufacture standard BS8887-220, set by the British Standards Institute. A full warranty is provided for the remanufactured products, equivalent to that of a new product. Notably, Canon claim that their remanufactured product range uses 90% fewer raw materials than the equivalent new products.[382]
- The UK-based computer company, Circular Computing, specialises in computer remanufacturing, which it carries out in a facility in the United Arab Emirates. The remanufacturing process follows BS8887-220 and BS8887-211 standards, set by the British Standards Institute. Remanufactured laptops are then resold through specific reseller partners at a 40% lower cost than equivalent new products. It is claimed that, for every laptop that is remanufactured and sold by Circular Computing, 316kg of carbon and 190,000 litres of water are avoided compared with the manufacture of an equivalent new laptop.[383] Interestingly, an academic literature source was identified that investigated the life cycle assessment of an unnamed UK-based laptop remanufacturing company operating in the Middle East. It calculated a global warming potential of 21kg

[380] Xerox (2018) 2018 Corporate Social Responsibility Report. Available at: link
[381] Whirlpool (2023) Saving You Money. Available at: link
[382] Canon Europe (2023) Sustainable IT: What’s the difference between Remanufactured and Refurbished? Available at: link
[383]Circular Computing (2023) We Help Companies Decarbonise Their IT Estate. Available at: link

carbon-e per remanufactured laptop, which was 94% less (or 310kg carbon-e less) than that of an average new laptop. 53% of the remanufacturing greenhouse gas emissions was associated with transportation of the laptops and parts, 39% was associated with electricity used for remanufacturing, 7% was associated with packaging and 1% was associated with new batteries required for some remanufactured laptops.[384]

8.2 Available sources

8.2.1 Literature review

The literature review identified Thirty sources that discussed the remanufacture of EEE as a resource efficiency measure. These comprised:

- Fifteen academic papers;
- Five website articles;
- Five technical studies;
- Four industry studies; and
- One policy document.

The relevant sources were considered of high applicability and credibility, when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.3, with twenty-one sources exhibiting an IAS of 4 or above. There were seven sources specific to the UK. Seven sources had publication dates of over ten years old. Because of the high overall IAS, a balanced approach was taken, considering the literature, stakeholder interview insights and workshop findings.

8.2.2 Interviews

In the stakeholder interviews, thirteen stakeholders commented on the remanufacture of EEE. There was consensus that the takeback of used EEE under the WEEE regulations is largely followed by larger producers but limited for smaller producers. As such, many stakeholders suggested that more enforcement on non-compliant producers was required to increase takeback which could offer remanufacturing opportunities. Stakeholders believed that the current rate of remanufacturing of EEE is low in the UK. However, smartphone trade-ins for newer models means that used smartphones are more commonly remanufactured. Stakeholders agreed that remanufactured EEE is generally less expensive to purchase than new EEE but offers the same functionality as new EEE. Furthermore, consumer demand for sustainable products was considered a driver since the greenhouse gas emission savings from remanufactured EEE tend to be very high. There was general consensus that since the remanufacturing process involves thorough disassembly, testing, replacing and reassembly, the reliability of the remanufactured EEE is maximised. Most stakeholders also believed that

[384] Yuksek et al. (2023) Sustainability Assessment of Electronic Waste Remanufacturing: The Case of Laptop. Available at: link

design for disassembly and modular design presented an opportunity for increasing EEE remanufacture. These were considered major drivers for the uptake of remanufactured EEE.

As for barriers, stakeholders agreed that there was a lack of awareness amongst consumers as to where to take used EEE for remanufacturing, meaning that many consumers may instead dispose or recycle their products. Similarly, indefinite storage of used EEE by consumers was commonly highlighted as a barrier to the availability of EEE products and parts for remanufacture. Older EEE could also be regarded as unfashionable or outdated by consumers, which could limit uptake of remanufactured EEE. There was consensus that in some cases, EEE was not economically feasible to remanufacture, with availability and affordability of replacement parts also being highlighted as a barrier to remanufacturing EEE. One stakeholder added that many manufacturers lack the facilities to remanufacture EEE. Finally, some stakeholders felt that there is more emphasis on recycling in the UK rather than remanufacture or reuse.

Overall, stakeholders felt that the rate of EEE remanufacturing is low in the UK, with limited regulatory compliance regarding used EEE takeback and availability and affordability of EEE and replacement parts being major barriers to improvement. However, the rigorous remanufacturing process and general cost and emissions savings compared with new EEE were considered drivers for increased rates of remanufactured EEE.

8.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 8. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academics, social enterprises, a trade body, a thinktank, a producer compliance scheme and an NGO. The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current and business-as-usual levels of efficiency. As for the maximum level of efficiency, only two stakeholders voted, who believed that the levels would be lower than proposed. However, no quantified levels were provided. Stakeholders discussed the issues facing higher levels of remanufactured EEE, with potentially illegal exports of returned EEE under warranty being a limiting factor for the access to spare parts and remanufactured EEE.

The level of engagement in the workshop was as follows:

- Six stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Five stakeholders actively contributed to verbal discussion, with two stakeholders contributing on the Teams chat.

8.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

8.3.1 Drivers

Table 24 below shows the main drivers for Measure 8. The most substantial drivers are shown in bold as voted for by stakeholders in the workshop.

Table 24: Drivers for EEE Measure 8

Description	PESTLE	COM-B
Remanufactured EEE is generally less expensive to purchase than new EEE.[385] [386] [387] [388]	**Economic**	**Opportunity – psychological**
Cost savings for manufacturers associated with raw materials, energy and waste management compared with new EEE.[389] [390] [391] [392] [393] [394] [395]	**Economic**	**Opportunity – psychological**
In certain cases, remanufacturing can be more profitable for manufacturers compared with recycling and manufacturing.[396] [397]	Economic	Opportunity – psychological
Technological advances in 3D printing for replacement parts and automation of disassembly and reassembly pose drivers for the ability to remanufacture EEE in a quicker and more cost-effective manner.[398]	Technological	Opportunity – physical

[385] Aydin and Mansour (2023) Investigating sustainable consumer preferences for remanufactured electronic products. Available at: link
[386] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[387] Nnorom and Osibanjo (2010) Overview of Prospects in Adopting Remanufacturing of End-of-Life Electronic Products in the Developing Countries. Available at: link
[388] LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
[389] Alkouh et al. (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link
[390] Ijomah and Chiodo (2010) Application of active disassembly to extend profitable remanufacturing in small electrical and electronic products. Available at: link
[391] Nnorom and Osibanjo (2010) Overview of Prospects in Adopting Remanufacturing of End-of-Life Electronic Products in the Developing Countries. Available at: link
[392] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[393] LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
[394] Stakeholder interviews
[395] Yuksek et al. (2023) Sustainability Assessment of Electronic Waste Remanufacturing: The Case of Laptop. Available at: link
[396] Ijomah and Chiodo (2010) Application of active disassembly to extend profitable remanufacturing in small electrical and electronic products. Available at: link
[397] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[398] European Environment Agency (2021) Contribution of remanufacturing to Circular Economy. Available at: link

Description	PESTLE	COM-B
Remanufacturing can mitigate risks associated with component and material shortages.[399] [400]	Technological	Capability – physical
Reduces waste arisings and can help businesses to meet certain sustainability goals.[401]	Environmental	Motivation – automatic
Design for disassembly, modularity and cross-compatibility of parts (i.e., commonality between products and brands) should increase the potential for remanufacturing EEE.[402]	Technological	Capability – physical
Helps manufacturers gain a better understanding of product design faults, functionality and performance, which can lead to improvements in design.[403]	Technological	Capability – psychological
Remanufactured EEE are given a full manufacturer's warranty, equivalent to that of new EEE.[404] This may improve consumer confidence and reassurance in remanufactured EEE.	Social	Motivation – automatic
Some companies follow remanufacturing standards, such as BS8887-220.[405] This may improve consumer confidence in remanufactured EEE.	Social	Opportunity – social
Extensive testing and cleaning of all components should make remanufactured EEE reliable.[406]	Technological	Capability – physical

[399] LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
[400] European Environment Agency (2021). Contribution of remanufacturing to Circular Economy. Available at: link
[401] LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
[402] Stakeholder interviews
[403] Alkouh et al. (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link
[404] IRP (2018) Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. A Report of the International Resource Panel. Available at: link
[405] British Standards Institute (2010) BS 8887-220;2010. Design for manufacture, assembly, disassembly and end-of-life processing (MADE) - The process of remanufacture. Specification. Available at: link
[406] Stakeholder interviews

Description	PESTLE	COM-B
Consumer demand for sustainable products, with remanufactured EEE resulting in raw material and greenhouse gas emission savings.[407]	Social	Motivation – reflective

Remanufactured EEE is generally less expensive to purchase than new EEE

One of the main drivers is that remanufactured EEE can cost less to purchase compared with new EEE. This also allows access to EEE for consumers who are unable to afford new EEE. In the workshop, four of the fifteen votes for the top three drivers were for this driver. This was the highest voted driver amongst workshop stakeholders.

Cost savings for manufacturers associated with raw materials, energy and waste management compared with new EEE

The process of remanufacturing EEE can provide various savings to manufacturers compared with the manufacture of new EEE. Firstly, the manufacturing stage of a product's lifecycle can be the most energy intensive stage for certain EEE products – such as laptops and smartphones which typically use lower amounts of energy during their use phase. As such, the reuse of existing components through remanufacture can reduce energy use by 20-80%.[408] [409] For instance, one study reviewing lifecycle comparisons of remanufactured EEE compared with new EEE found energy savings ranging from 14% for refrigerators, 32% for washing machines, 44% for dishwashers and 80% for personal computers.[410] Secondly, remanufacture provides manufacturers with potential costs savings on fewer raw materials. For instance, one study assessing a laptop remanufacturing company found that new batteries were the most common new replacement parts required for their remanufactured laptops but accounted for only one for every thirteen and a half remanufactured laptops.[411] Finally, manufacturers may reduce their waste management fees as more end-of-use components are being salvaged for reuse. For example, one study reviewing lifecycle comparisons of remanufactured EEE compared with new EEE found waste arisings to reduce by between 35% and 47% for photocopiers.[412] In the workshop, two of the fifteen votes for the top three drivers were for this driver.

[407] Stakeholder interviews
[408] Ijomah and Chiodo (2010) Application of active disassembly to extend profitable remanufacturing in small electrical and electronic products. Available at: link
[409] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[410] European Environment Agency (2021) Contribution of remanufacturing to Circular Economy. Available at: link
[411] Yuksek et al. (2023). Sustainability Assessment of Electronic Waste Remanufacturing: The Case of Laptop. Available at: link
[412] European Environment Agency (2021) Contribution of remanufacturing to Circular Economy. Available at: link

8.3.2 Barriers

Table 25 below shows the main barriers for Measure 8. The most substantial barriers are shown in bold as voted for by stakeholders in the workshop.

Table 25: Barriers for EEE Measure 8

Description	PESTLE	COM-B
Some EEE may be designed in such a way that is challenging to disassemble and reassemble. For instance, soldering, welding and plastic melts, that can cause damage to the product when dismantled.[413] [414] [415]	**Technological**	**Capability – physical**
Producers and OEMs may be reluctant to sell remanufactured EEE at a lower price than new EEE equivalents, as it may undermine sales of new EEE.[416]	**Economic**	**Opportunity – social**
Consumers may dispose of or recycle used EEE, which is otherwise suitable for remanufacture.[417] [418] [419]	Environmental	Capability – psychological
Remanufacture may not be economically feasible for certain EEE products. This may be due to labour, replacement parts, transportation and/or other costs that exceed the value of the product.[420] [421]	Economic	Opportunity – psychological
Limited or no availability of specific replacement parts, creating long lead	Technological	Capability – physical

[413] Lonf et al. (2016) Technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China. Available at: link
[414] Hatcher et al. (2013) Design for remanufacturing in China: a case study of electrical and electronic equipment. Available at: link
[415] Alkouh et al. (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link
[416] Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
[417] Rosa and Terzi (2016) Waste Electrical and Electronic Equipments versus End-of-life Vehicles: A State of the Art Analysis and Quantification of Potential Profits. Available at: link
[418] Romero de Brito et al. (2022) Reverse remanufacturing of electrical and electronic equipment and the circular economy. Available at: link
[419] Stakeholder interviews
[420] Green Alliance (2015) A circular economy for smart devices. Available at: link
[421] Stakeholder interviews

Description	PESTLE	COM-B
times.[422] [423] This may be particularly relevant for computer processing parts and less common brands.		
Skilled labour and knowledge are needed to understand the technical requirements for various products. A lack of skilled labour would pose a barrier to the remanufacture of EEE.[424] [425]	Economic	Capability – physical
A large variety of parts are used between products and manufacturers. Part compatibility is therefore often restricted to specific brands or models. In some cases, using alternative parts may result in the loss of certain functionality.[426] [427] [428] [429] [430]	Technological	Capability – physical
Consumers may be concerned about the lifespan and electrical safety of remanufactured EEE.[431]	Social	Capability – psychological
There may be a limited price difference between new and remanufactured EEE. As such, some consumers may be willing to pay more for new EEE.[432]	Economic	Opportunity – social
Some remanufactured EEE may cost more to operate than new EEE with higher efficiency ratings (e.g., water and energy consumption per washing cycle). This may	Economic	Capability – physical

422 LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
423 Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
424 LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
425 Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
426 Dindarian et al (2012) Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom. Available at: link
427 LightGuide (2022) Electronics Remanufacturing Explained. Available at: link
428 Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
429 Alkouh et al. (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link
430 Stakeholder interviews
431 Stakeholder interviews
432 Istudor et al. (2023) Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment. Available at: link

Description	PESTLE	COM-B
result in a higher overall cost to the consumer.[433]		
Lack of EEE designed for remanufacture and modular design, partly due to a lack of awareness of eco-design within the sector.[434]	Technological	Capability – physical
Limited availability of OEM original specification information to facilitate remanufacture.[435] [436]	Political	Opportunity – social
Limited remanufacturing infrastructure and return channels.[437] This may limit the amount of used EEE sent for remanufacture and subsequently purchased.	Technological	Capability – physical
OEMs may only be inclined to design EEE for remanufacture if they engage in remanufacturing.[438]	Political	Opportunity – social
Negative consumer perception towards remanufactured products, partly due to misunderstanding of the process.[439] [440] [441]	Social	Motivation – automatic
Capital investment in equipment/tools is required that may only be compatible with certain product types and materials.[442]	Economic	Capability – physical
Disassembly and testing of EEE components can be time consuming and	Technological	Capability – physical

[433] Hischier and Böni (2021) Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study. Available at: link
[434] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[435] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[436] Hatcher et al. (2013) Design for remanufacturing in China: a case study of electrical and electronic equipment. Available at: link
[437] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[438] Gray and Charter M. (2008) Remanufacturing and Product Design. Available at: link
[439] Aydin and Mansour (2023) Investigating sustainable consumer preferences for remanufactured electronic products. Available at: link
[440] Aydin and Mansour (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link
[441] Stakeholder interviews
[442] Aydin and Mansour (2023) Remanufacturing of Industrial Electronics: A Case Study from the GCC Region. Available at: link

Description	PESTLE	COM-B
expensive and requires detailed knowledge of the product.[443]		

Some EEE may be designed in such a way that makes it challenging to disassemble and reassemble

Components can often be assembled in such a way that makes them difficult to remove without causing damage to the components or product. For example, the use of sealed units and anti-tamper screws may protect EEE from damage or theft, but it can cause difficulties and damages during remanufacture. This can make remanufacture more labour intensive, expensive and potentially renders the EEE uneconomically viable for remanufacture. In the workshop, three of the seventeen votes for the top three drivers were for this driver. This was the joint-highest voted driver amongst workshop stakeholders.

Producers and OEMs may be reluctant to sell remanufactured EEE

Many producers and OEMs sell new EEE as their core product range, encouraging consumers to purchase their range of EEE. By selling remanufactured EEE at a lower price than their new EEE, but with the same warranty as new EEE, they might undermine sales for their new EEE. As such, producers and OEMs may be reluctant to venture into remanufactured EEE as a business model. In the workshop, three of the seventeen votes for the top three drivers were for this driver. This was the joint-highest voted driver amongst workshop stakeholders.

8.4 Levels of efficiency

Table 26: Levels of efficiency for EEE Measure 8

Indicator: % of EEE that is remanufactured for reuse			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	1 – 10%	80%	10 – 15%
Evidence RAG	Green	Red	Amber

8.4.1 Current level of efficiency

There was limited quantitative data in the literature surrounding the rate of remanufactured EEE, despite it being evident that it is a service that is being offered by manufacturers and third

[443] Stakeholder interviews

parties. One UK study, with an IAS of 4, stated that the size of the UK remanufacturing market was valued at £5 billion in 2003, compared with the manufacturing market which was valued at £447 billion in 2004.[444] However, a more recent source, with an IAS of 4, stated that the UK's remanufacturing market was valued at £2.4 billion in 2014, with potential to increase to £5.6 billion.[445] Despite the differences, the remanufacturing market is a small fraction of the total manufacturing market. Although these sources are not referring specifically to EEE remanufacturing, the ratio of remanufacturing to manufacturing could be applied to EEE. Furthermore, the EEE remanufacturing market has likely increased in recent years due to consumer demand for sustainable products – including remanufactured EEE.

One study, with an IAS of 5 and focussing on the US market, stated that 35% of consumers claimed that they have purchased remanufactured EEE.[446] Another source with an IAS of 5 stated that there were US$50 million of annual sales of remanufactured EEE in the US.[447] However, it is unclear what the size of the US EEE market is as a whole, with sources for ranging from US$92.15 billion [448] to US$155 billion [449] to US$159 billion.[450] Regardless, the remanufactured EEE market is a small fraction of the total EEE market in the US.

A European study, with an IAS of 5, investigated the remanufacturing market for different sectors using a literature review and stakeholder interviews. It estimated that the European EEE remanufacturing market (measured by turnover) was worth €3.1 billion in 2015, adding that 1.1% of EEE produced in 2015 was remanufactured EEE. It provided further detail that the UK and Ireland's EEE remanufacturing market (measured by turnover) was worth €190 million in 2015, employing approximately 1,700 people. The report also estimated that 5.87 million used components were reused for remanufactured EEE in the UK and Ireland.[451] A follow-up report to this European study suggested that there was insufficient evidence to indicate how the EEE remanufacturing market had developed from 2015 to 2021, but it was believed that the increase was minimal.[452]

From the stakeholder interviews, stakeholders agreed that the takeback and remanufacture of used EEE is evident in the UK, with the rate of takeback being higher for larger retailers and large domestic appliances compared with smaller retailers. The stakeholders estimated 50-75% of smaller retailers to be compliant with WEEE regulations requirements for retailer takeback of certain used EEE products.[453] However, another stakeholder highlighted that the lack of transparent reporting means that although retailers claim that they offer the service of used EEE take-back, it is unclear as to how many used EEE products are remanufactured. Other stakeholders indicated that the rate of EEE remanufacture is 'not very high' and 'low',

[444] Gray and Charter (2008) Remanufacturing and Product Design. Available at: link
[445] Perella, M. (2014) UK remanufacturing worth £5.6bn if business model can be cracked. Available at: link
[446] Aydin and Mansour (2023) Investigating sustainable consumer preferences for remanufactured electronic products. Available at: link
[447] Flygansvaer et al. (2018) Exploring the pursuit of sustainability in reverse supply chains for electronics. Available at: link
[448] Mordor Intelligence (2023) US Electronics & Appliance Stores Market Size. Available at: link
[449] Statisata (2023) Consumer Electronics – United States. Available at: link
[450] IBISWorld (2022) Consumer Electronics Stores in the US. Available at: link
[451] Parker et al. (2015) Remanufacturing Market Study. For Horizon 2020, November 2015. Available at: link
[452] European Environment Agency (2021) Contribution of remanufacturing to Circular Economy. Available at: link
[453] The Waste Electrical and Electronic Equipment Regulations 2013. Available at: link

and that indefinite storage of used EEE by consumers creates a lag in EEE and reusable parts being available for remanufacture.

Therefore, based on the low market share of remanufactured EEE in the EEE sector and the qualitative input from stakeholders, it was initially assumed that the displacement of new EEE from remanufactured EEE was low. However, due to limited quantitative data on recent levels of EEE remanufacturing, it was initially estimated, with an amber RAG evidence rating, that the current level of efficiency was between 1% and 10%.

In the workshop, four of the seventeen stakeholders voted on the current level of efficiency – consisting of two academics, one producer compliance scheme and one manufacturer. There was therefore moderate representation from the EEE sector. Of the four stakeholders that voted, all four voted for a current level of efficiency between 1% and 10%, all with medium confidence. No further information to quantify the exact level of efficiency was provided. One trade body stakeholder explained that remanufacturing is more common for commercial EEE, with consumer EEE often being refurbished rather than remanufactured. A producer compliance scheme stakeholder added that consumers may be limited by the age of EEE, so remanufactured EEE that is over a certain age may not appeal to all consumers. Additionally, one manufacturer stakeholder explained that remanufactured EEE is more common in the UK, but that it is important that consumers are provided with safe and durable remanufactured EEE. Overall, stakeholders tended to agree with the current level of efficiency being between 1% and 10%. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 8 is between 1% and 10%, with a green RAG evidence rating. This increase from amber to green RAG evidence rating is based on consensus from stakeholders at the workshop, all with medium confidence.

8.4.2 Maximum level of efficiency in 2035

Theoretically, any product that has been manufactured can be remanufactured. If EEE has been designed with remanufacture in mind used EEE is returned to companies for remanufacture and there is consumer demand for remanufactured EEE, then the maximum level of efficiency has the potential to be high. One source, with an IAS for 4, discussed the maximum remanufactured content small EEE. It stated that 85% (by weight) of a product could come from used components and that remanufactured small EEE could have a comparable quality to the equivalent new small EEE.[454] Additionally, Xerox manage to incorporate 70-90% machine component reuse by weight.

With reference to used EEE takeback, some stakeholders indicated that it was technically possible for 100% compliance from retailers on their takeback obligations. However, a 100% return rate from consumers would be unlikely.

No sources were identified that referred to the maximum potential market penetration of remanufactured EEE, which would prevent the manufacture and consumption of new EEE. Stakeholders agreed that there is high potential and that the maximum level is far higher than

[454] Ijomah and Chiodo (2010) Application of active disassembly to extend profitable remanufacturing in small electrical and electronic products. Available at: link

the current level. Some stakeholders suggested up to 80-90% of EEE could be remanufactured, but no evidence was provided to support this. Another stakeholder indicated that the potential for remanufactured EEE is higher for high volume EEE, where the supply of parts would be reliable.

As stated, although it may be technically possible to remanufacture any product that have been manufactured (if design allows), there are factors that limit the maximum technical efficiency of market capacity of remanufactured products. Firstly, if it is technically possible for 85% of a remanufactured product to contain reused parts, then additional materials and components will be required. Secondly, it will not be economically feasible to remanufacture all EEE, and replacement parts may not be available for all EEE. Therefore, the maximum level of efficiency was initially estimated at 80%. However, the lack of quantitative data to support this meant that this was given a red RAG evidence rating.

In the workshop, five of the seventeen stakeholders voted on the maximum level of efficiency by 2035 – consisting of two academics, one social enterprise, one producer compliance scheme and one manufacturer. There was therefore moderate representation from the EEE sector. Of the five stakeholders that voted, two voted for a maximum level of efficiency of below 80%. Both of these votes were with high confidence. No further information to quantify the exact level of efficiency was provided. The three remaining votes were for “Don’t Know”. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency by 2035 for Measure 8 is 80%, with a red RAG evidence rating. Whilst this is considered high, without further quantified estimates, the initial estimate has been retained.

8.4.3 Business-as-usual in 2035

As featured earlier, one European study, with an IAS of 5, investigated the remanufacturing market for different sectors using a literature review and stakeholder interviews. It estimated that the European EEE remanufacturing market (measured by turnover) was worth €3.1 billion in 2015, adding that 1.1% of EEE produced in 2015 was remanufactured EEE. It provided further detail that the UK and Ireland’s EEE remanufacturing market (measured by turnover) was worth €190 million in 2015, employing approximately 1,700 people. The report also estimated that 5.87 million used components were reused for remanufactured EEE in the UK and Ireland. From stakeholder insight and interviews with industry experts, three different scenarios were created for 2030. The first scenario was “Base case”, similar to a business-as-usual situation, in which EEE remanufacture was modelled using a 5% per annum market growth rate. Under this “Base case” scenario, the EEE remanufacturing market in Europe was valued at €6.5 billion by 2030, with a carbon saving of 369,000 tonnes. The second scenario was “Stretch”, in which policies and promotional activities would improve remanufacturing. Under this “Stretch” scenario, EEE remanufacturing was modelled with a 100% market growth rate by 2030, compared with the “Base case”. By 2030, the European EEE remanufacturing market was valued at €13 billion under the “Stretch” scenario, with a carbon saving of 737,000 tonnes. The third scenario was “Transformation”, in which highly effective policies and promotional activities would vastly increase remanufacturing. Under this “Transformation” scenario, EEE remanufacturing was modelled with a 200% market growth rate by 2030, compared with the “Base case”. By 2030, the European EEE remanufacturing market was valued at €19.4 billion under the “Transformation” scenario, with a carbon saving of 1,106,000 tonnes.[455]

Whilst most EEE manufacturing occurs in Asia, remanufacturing activities often take place in the same country where the used EEE is sourced and sold. However, there was a general agreement from stakeholders that the rate of remanufacture and consequently its market penetration will likely remain low, although there would likely be variation between product categories. Two stakeholders indicated that the level could increase to 30% for small household appliances and to 40% for other EEE. Another stakeholder indicated that the level of efficiency could increase to 70% for large domestic appliances.

One stakeholder highlighted that remanufactured EEE could increase if regulatory requirements were further enforced. Another stakeholder believed that EEE remanufacture was not economically feasible for most manufacturers in the UK. Finally, one stakeholder explained that many smaller manufacturers do not have their own manufacturing factories and so rely on other factories to produce parts. They therefore do not currently have the facilities to conduct remanufacturing activities. They added that it was too expensive for them to set up their own remanufacturing facility, particularly with the limited rate of takeback across the different EEE product categories.

Therefore, based on limited quantitative and qualitative information, it was initially believed that the business-as-usual level of efficiency would be 10-15%, with a red RAG evidence rating.

In the workshop, five of the seventeen stakeholders voted on the business-as-usual level of efficiency by 2035 – consisting of two academics, one social enterprise, one producer compliance scheme and one manufacturer. There was therefore moderate representation from the EEE sector. Of the five stakeholders that voted, four voted for a business-as-usual level of efficiency of between 10% and 15%. Two of these votes were with high confidence and two were with medium confidence. No further information to quantify the exact level of efficiency was provided. The other remaining vote was for “Don’t Know”. Trade body and NGO stakeholders discussed the issues surrounding warranty returns, with many of the returned used EEE often being exported to other countries. These illegal exports of potential WEEE were highlighted as a barrier facing higher rates of remanufactured EEE. Overall, stakeholders tended to agree with the business-as-usual level of efficiency by 2035 being between 10% and 15%. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the business-as-usual level of efficiency by 2035 for Measure 8 is between 10% and 15%, with an amber RAG evidence rating. This increase from red to amber RAG evidence rating is based on consensus from stakeholders at the workshop, with a mix of high and medium confidence.

[455] Parker et al. (2015) Remanufacturing Market Study. For Horizon 2020, November 2015. Available at: link

9.0 Measure 9 – Recycling of WEEE

9.1 Electricals resource efficiency measure

9.1.1 Description

The processing of end-of-life EEE (WEEE) into its raw material form for use as secondary feedstock in the production of new products. This recycled feedstock is not necessarily for new EEE. Recycling reduces reliance on virgin materials for manufacturing new products, thereby avoiding greenhouse gas emissions associated with the extraction and processing of raw materials.

Once EEE have reached the end of their useable life and cannot be reused, repaired, refurbished or remanufactured, the materials should be recycled in order to avoid resource loss to landfill and/or incineration. There are various materials used for EEE, including metals, plastic and critical raw materials. The composition of the materials can vary between products.

WEEE recycling in the UK is largely focused on meeting the separate collection targets and the mandatory recovery targets for each key category of WEEE as per the WEEE Regulations.[456] With the exception of refrigeration equipment and certain other items (such as CRT televisions and monitor screens), WEEE tends to be collected and treated mixed (e.g., mixed small WEEE collections at HWRCs). As such, there is often a wide range of equipment, components, and materials that needs to be separated, recycled and disposed, where required. In the UK, most consumers are required to take WEEE to dedicated recycling points – such as at HWRCs, recycling points and at certain retail stores that are obligated according to the WEEE Regulations. Additionally, many retailers and producers offer free collections of used EEE from consumers upon delivery of new replacement EEE, as required in the WEEE Regulations. Despite the opportunities for WEEE recycling in the UK, not all WEEE is managed correctly. For example, one study estimated that of the 1.45 million tonnes of electrical waste that was available for reuse or recycling in 2017, over a third was incorrectly disposed of as residual waste, indefinite storage of used EEE by consumers, stolen or illegally exported.[457] As such, there is potential to divert much of this incorrectly managed WEEE for recycling.

The recycling of WEEE must be carried out at an approved treatment facility in the UK or through an approved exporter for treatment outside of the UK. In most cases, WEEE is shredded, often by using metal flails, hammer mills or blades. Automated and manual separation techniques (such as Near Infra-Red sorters, magnets, and manual picking lines) are then used to separate the shredded metals, plastics, screen materials, printed circuit boards (PCBs), batteries and other materials. This sorted material is then sent on for recycling into new products, with rejected material unsuitable for recycling being treated as residual waste. Rejected material may include plastics, since it can be difficult for many treatment facilities to

[456] The Waste Electrical and Electronic Equipment Regulations 2013. Available at: link
[457] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link

correctly separate contaminated plastics (such as the presence of hazardous flame retardants) from uncontaminated plastics. As such, a large proportion of WEEE plastic is often not recycled. Since approximately 30% of WEEE is believed to be plastic, by weight, this poses a barrier to the recycling rates of WEEE sent for recycling.[458]

Although there may be reusable or repairable parts within WEEE feedstock, given the unfeasibility of WEEE disassembly prior to shredding, much of the WEEE sent to treatment facilities is shredded and sent on for recycling. However, where possible, the WEEE Regulations state that whole reusable EEE products sent to a treatment facility should be prioritised for reuse.[459] One study found that some AATFs in the UK reported 5% of displays, 2.44% of cooling equipment, 0.59% of large household appliances, and 0.49% of small mixed WEEE were diverted for reuse.[460]

Where recycled material is used instead of virgin materials, this contributes to delivering resource efficiency. As such, the availability of recycled material for manufacturing new products is reliant on the collection and recycling of waste material. As set out in the Defra's 'Maximising Resources, Minimising Waste', the UK Government is working with their counterparts in Scotland, Wales and Northern Ireland to consult on improvements to the current UK-wide WEEE Regulations.[461] The consultation was opened to the public on 28 December 2023, seeking views on reforms to the Waste Electrical and Electronic Equipment Regulations 2013.[462]

9.1.2 Measure indicator

The indicator that was selected was the **percentage recycling rate of WEEE**. This includes all of the materials included in WEEE products and their return to raw material form for use in the manufacturing process. The percentage of WEEE that is recycled is defined by the amount of WEEE material sent for reprocessing into new products, considering losses and rejected material from the treatment facilities.

9.1.3 Examples in practice

Although the recycling of WEEE varies depending on the input feedstock and the target material, there are a number of common methods that are used to extract materials at the ATFs and AATFs. These include:

- Disassembly (largely using manual labour), whereby hazardous materials are separated using mechanical separation techniques. This approach may be used for fridges and CRT televisions and monitors.

[458] Stubbings et al. (2021) Assessment of brominated flame retardants in a small mixed waste electronic and electrical equipment (WEEE) plastic recycling stream in the UK. Available at: link
[459] The Waste Electrical and Electronic Equipment Regulations 2013. Available at: link
[460] Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link
[461] Defra (2023) The waste prevention programme for England: Maximising Resources, Minimising Waste. Available at: link
[462] Defra (2023) Consultation on reforming the producer responsibility system for waste electrical and electronic equipment 2023. Available at: link

- Shredding is a common process used WEEE, whereby WEEE is shredded using mechanical methods (such as hammer mills) to separate the various materials used to construct EEE.
- Manual picking lines, Near InfraRed scanning sorters, magnets and eddy current separators for sorting the shredded material.
- Where applicable, the sorting of plastics generally involves sink-float sorting techniques to sort plastics by polymer.
- Smelting (pyrometallurgy), which extracts precious metals from the PCBs to create metal alloys.
- Various forms of PCB reprocessing are also used or being developed – including enzyme treatments (bioleaching of metals), acid digestion and solvent extraction techniques (hydrometallurgy) which are usually applied to the shredded/powdered material to extract a specific target material.
- Refining, where the outputs from the hydrometallurgy and pyrometallurgy are refined to increase purity, for example of precious metals.
- Circuit boards and batteries currently tend to be exported to Umicore in Europe.[463] However, the Royal Mint in the UK have partnered with Excir, a Canadian start-up company, to build a facility capable of recovering precious metals, such as gold, from PCBs. The facility is expected to process over 70 tonnes of UK-sourced PCBs per week.[464] Similarly, the UK-based jewellery company, Lylie, extracts precious metals, such as gold and silver, from PCBs to be used for rings, necklaces and other high value jewellery.[465] Other jewellers also use this novel recycling/upcycling method to extract and recycle precious metals from WEEE into high value jewellery.[466]
- Some WEEE reprocessors, such as Recycling Lives in Lancashire, and GAP Group in the Northeast, do more manual disassembly and refurbishment work to help recover greater value from the WEEE, focusing on reuse of whole items and components, which are tested and resold online.

9.2 Available sources

9.2.1 Literature review

The literature review identified forty-four sources that discussed WEEE recycling as a resource efficiency measure. These comprised:

- Seventeen academic papers;
- Thirteen technical studies;

[463] Umicore (2023) Excellence in recycling. Available at: link
[464] The Royal Mint (2023) Precious Metal Recovery from Electronic Waste. Available at: link
[465] Lylie (2023) Salvaged Gold & Silver. Available at: link
[466] Recycle Your Electricals (2023) Sustainable jewellery – the beauty of recycling. Available at: link

- Nine website articles; and
- Five policy documents.

The relevant sources were considered of high applicability and credibility, when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.2 (out of 5), with thirty-five sources exhibiting an IAS of 4 or above. There were eighteen sources specific to the UK. Five sources had publication dates of over ten years old. Because of the high overall IAS, a balanced approach was taken, considering the literature, stakeholder interview insights and workshop findings.

9.2.2 Interviews

In the stakeholder interviews, twelve stakeholders commented on WEEE recycling. There was consensus that AATFs are meeting the WEEE Regulations recycling rate targets, with a high rate of metals being recovered and recycled, in particular. Stakeholders agreed that the recovery and recycling rates for CRMs are low, but that gold is generally recovered and recycled from WEEE. It was noted that WEEE plastic poses a particular barrier to increasing WEEE recycling rates due to the risk of POPs being present in the plastic, meaning plastic can end up being treated as residual waste. However, stakeholders believed that the recent WEEE Regulations consultation acts as a driver to the increase of WEEE recycling. Additionally, stakeholders felt that cost and carbon savings associated with recycled material compared with virgin material could increase demand for recycled material. This could act as a driver for increasing WEEE recycling rates.

In terms of barriers, stakeholders explained that rising energy costs could make WEEE recycling economically unfeasible. Additionally, limited WEEE feedstock due to limited collections and policy incentives for WEEE recycling posed a barrier to the increase of WEEE recycling rates. Stakeholders added that POPs and other hazardous materials in WEEE plastics limited WEEE recycling rates. They added that a lack of trust from consumers that WEEE would be recycled could also limit recycling rates, with some consumers disposing their WEEE incorrectly. Finally, unofficial scrap metal recycling of WEEE and free rider producers were also mentioned as being barriers to increasing WEEE recycling rates.

Overall, stakeholders believed that whilst WEEE recycling rates could increase, it would unlikely increase naturally, with metal recovery and recycling rates already high and plastic often being rejected due to POPs risks. It was believed that the feedstock of WEEE would need to increase, and that policy intervention would be required to support the increase in WEEE recycling.

9.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 9. Overall, input from the stakeholders represented a good coverage of the EEE sector, with discussions and votes being active from academics, social enterprises, a producer compliance scheme, a thinktank and an NGO. The majority of stakeholders that voted on the levels of efficiency agreed with the proposed current level of efficiency. As for the business-as-usual and maximum levels of efficiency, most stakeholders believed the levels of efficiency would be higher than proposed. However, no quantified levels were provided.

The level of engagement in the workshop was as follows:

- Five stakeholders across industry and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion, with two stakeholders contributing on the Teams chat.

9.3 Drivers & Barriers

The drivers and barriers influencing this Measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

9.3.1 Drivers

Table 27 below shows the main drivers for Measure 9. The most substantial drivers are shown in bold as voted for by stakeholders in the workshop.

Table 27: Drivers for EEE Measure 9

Description	PESTLE	COM-B
Kerbside recycling services for small WEEE are being investigated and trialled in some Local Authorities. This may increase WEEE recycling rates through improved recycling convenience.[467]	**Technological / Environmental**	**Capability – physical**
High economic value for certain materials within WEEE, which may be an income stream for treatment facilities.[468]	**Economic**	**Motivation – automatic**
Producer take-back is mandated according to the WEEE Regulations [469]	Legal	Motivation – automatic

[467] Material Focus (2022) Update to A Review (Economic and Environmental) of Kerbside Collections for Waste Electricals. Final Report. Available at: link
[468] CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
[469] The Waste Electrical and Electronic Equipment Regulations 2013. Available at: link

Description	PESTLE	COM-B
and is being further developed (e.g., WEEE Regulations consultation).[470] [471]		
Legislative restrictions and bans of certain hazardous substances that limit recycling.[472]	Legal	Capability – physical
Procurement strategies requiring that minimum percentage of materials need to be derived from recycled sources.[473]	Environmental	Opportunity – social
Recycled material may be cheaper than primary raw material.[474] This may increase demand for recycled content.	Economic	Opportunity –psychological
EPR encourages producers to design EEE for recycling.[475]	Legal	Motivation – automatic
Substitution of materials that are more easily recycled.[476]	Technological	Capability – physical
Technological advances in WEEE recycling and novel upcycling business models may increase WEEE recycling rates.[477] [478]	Technological	Opportunity – physical
Improved brand reputation from increased recycling rates.[479]	Social	Motivation – automatic
Requirement to become resource independent, especially for critical raw materials.[480]	Environmental	Motivation – automatic

470 Brix-Asala et al. (2018) Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management. Available at: link
471 Stakeholder interviews
472 CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
473 Eunomia Research & Consulting (2016) Procuring for: Repair, Re-use and Remanufacturing. Available at: link
474 Brix-Asala et al. (2018) Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management. Available at: link
475 Lonf et al. (2016) Technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China. Available at: link
476 O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
477 The Royal Mint (2023) Precious Metal Recovery from Electronic Waste. Available at: link
478 Recycle Your Electricals (2023) Sustainable jewellery – the beauty of recycling. Available at: link
479 Stakeholder interviews
480 Stakeholder interviews

Kerbside recycling services for small WEEE

Currently in the UK, around 22% of households are offered kerbside recycling for their small WEEE – such as kettles, toasters and portable CD players. However, it is estimated that over 155,000 tonnes of WEEE are disposed of in residual waste in the UK each year, with the majority being small WEEE. As such, it is believed that expanding kerbside recycling services of small WEEE throughout the UK could divert much of this small WEEE away from residual waste and into recycling.[481] In the workshop, three of the thirteen votes for the top three drivers were for this driver. This was the second highest voted driver amongst workshop stakeholders.

High economic value for certain materials within WEEE

EEE are often manufactured using various high-value materials, such as steel, aluminium, CRMs and precious metals including silver and gold. As such, recovering these high-value materials can pose as an income stream for recycling firms. In the workshop, four of the thirteen votes for the top three drivers were for this driver. This was the highest voted driver amongst workshop stakeholders.

9.3.2 Barriers

Table 28 below shows the main barriers for Measure 9. The most substantial barriers are shown in bold as voted for by stakeholders in the workshop.

Table 28: Barriers for EEE Measure 9

Description	PESTLE	COM-B
Cost of recycled material can be higher than that of virgin material, resulting in reduced demand for	**Economic**	**Opportunity – psychological**

[481] Material Focus (2022) Update to A Review (Economic and Environmental) of Kerbside Collections for Waste Electricals. Final Report. Available at: link

Description	PESTLE	COM-B
recycled material.[482] [483] [484] [485] [486] [487] [488] [489] [490] [491]		
Limited WEEE recycling infrastructure in the UK may result in high recycling costs.[492] [493] [494] [495] [496]	**Technological**	**Capability – physical**
Use of flame retardants and other hazardous substances restricts recycling potential, such as WEEE plastics.[497] [498] [499]	**Technological**	**Capability – physical**
Limited supply chain communication that connects collectors with recyclers, and recyclers with manufacturers.[500] [501] [502]	**Technological**	**Capability – psychological**

[482] WEEE Forum (2021) Recycling Critical Metals in E-Waste: Make it the Law. Available at: link
[483] Schmid, M. (2020) Challenges to the European automotive industry in securing critical raw materials for electric mobility: the case of rare earths. Available at: link
[484] Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
[485] Lonf et al. (2016) Technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China. Available at: link
[486] Bhuie et al. (2004) Environmental and economic trade-offs in consumer electronic products recycling: a case study of cell phones and computers. Available at: link
[487] O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[488] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[489] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[490] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[491] Stakeholder interviews
[492] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[493] Royal Society of Chemistry (2019). Critical raw materials in waste electrical and electronic equipment. Available at: link
[494] O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[495] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[496] Stakeholder interviews
[497] CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
[498] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[499] Stakeholder interviews
[500] Royal Society of Chemistry (2019) Critical raw materials in waste electrical and electronic equipment. Available at: link
[501] O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[502] TCO Certified (2020) Circular IT Management in Practice. Available at: link

Description	PESTLE	COM-B
Commercially scaled technology is not currently available that separates materials from complex component matrices, including effective pre-processing technologies.[503] [504] [505]	Technological	Capability – physical
Limited WEEE feedstock and inconsistent quality.[506] [507] [508] [509] [510]	Technological	Capability – physical
Consumers may lack awareness and/or convenience to correctly recycle their WEEE. This may result in WEEE being incorrectly placed in residual waste, dry mixed recycling, the indefinite storage of used EEE by consumers or fly tipping.[511]	Social	Motivation – automatic
Recycling processes can vary depending on WEEE or target material, making it expensive to design and build suitable treatment facilities.[512] [513] [514] [515] [516]	Technological	Capability – physical

[503] Royal Society of Chemistry (2019) Critical raw materials in waste electrical and electronic equipment. Available at: link
[504] Fraunhofer IZM (2016) How sustainable is the Fairphone 2? Results of an expert survey. Available at: link
[505] Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
[506] Brix-Asala et al. (2018) Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management. Available at: link
[507] O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[508] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[509] TCO Certified (2020) Circular IT Management in Practice. Available at: link
[510] Stakeholder interviews
[511] Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link
[512] Brix-Asala et al. (2018) Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management. Available at: link
[513] O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: link
[514] Tan et al. (2016) Biodegradable electronics: cornerstone for sustainable electronics and transient applications. Available at: link
[515] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[516] Stakeholder interviews

Description	PESTLE	COM-B
An increasing use of plastic may limit WEEE recycling potential.[517] With WEEE plastic often not being recycled, this may be a particular limiting factor.	Economic	Capability – physical
Limited Government funding for WEEE sorting and recycling infrastructure.[518] [519] [520]	Economic	Opportunity – psychological
Lack of manufacture willingness or ability to engage in CRM projects that will provide access to a secure supply of recycled material.[521]	Technological	Capability – physical
Lack of eco-modulation and EPR schemes regulated by fees on materials that are not compatible with recycling.[522] [523] [524]	Legal	Motivation – automatic
Lack of a mandated, exhaustive list of permitted materials and substances, which is restricted to those that are recyclable and non-hazardous.[525]	Legal	Motivation – automatic
Lack of consumer trust that products actually enter the recycling process, partly due to a lack of reporting requirements.[526]	Technological	Motivation – automatic

Cost of recycled material can be higher than that of virgin material, resulting in reduced demand for recycled material

[517] CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
[518] UK Parliament (2020) Electronic Waste and the Circular Economy. Available at: link
[519] WEEE Forum (2021) Recycling Critical Metals in E-Waste: Make it the Law. Available at: link
[520] Stakeholder interviews
[521] Schmid, M. (2020) Challenges to the European automotive industry in securing critical raw materials for electric mobility: the case of rare earths. Available at: link
[522] DSS (2022) The eco-modulation of producers' financial obligations for WEEE in the UK. Available at: link
[523] European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
[524] Stakeholder interviews
[525] Stakeholder interviews
[526] Stakeholder interviews

The most commonly mentioned barrier to WEEE recycling from stakeholders and in the literature was the high costs associated with the treatment facility equipment required for recycling. Furthermore, virgin materials were claimed to often be cheaper than recycled materials, which may disincentivise and limit WEEE recycling.

This high cost associated with WEEE recycling, combined with different recycling approaches often being required for certain WEEE products, may limit recycling efficiencies and capture rates of recyclable material. In the workshop, three of the fourteen votes for the top three drivers were for this driver. This was the joint-highest voted driver amongst workshop stakeholders.

Limited WEEE treatment facility infrastructure (collection and reprocessing)

Another commonly mentioned barrier is the lack of infrastructure to facilitate WEEE recycling. This included limited kerbside collection services for small WEEE, limited material sorting efficiencies and limited WEEE disassembly and material extraction methods to capture high value materials. In the workshop, three of the fourteen votes for the top three drivers were for this driver. This was the joint-highest voted driver amongst workshop stakeholders.

Use of flame retardants and other hazardous substances restricts recycling potential

The use of hazardous substances in EEE may result in treatment facilities rejecting WEEE plastic, since identification and sorting of contaminated WEEE plastic is challenging. As such, a large proportion of WEEE plastic is often not recycled. Since approximately 30% of WEEE is believed to be plastic, by weight, this poses a barrier to the recycling rates of WEEE sent for recycling.[527]

Lack of supply chain optimisation

There may be a lack of communication between actors in the WEEE operational chain. This may mean that the transfer and treatment of WEEE is not so efficient. Although none of the workshop stakeholders voted for this barrier as a key barrier, it was discussed by stakeholders. It was viewed by several stakeholders as a major barrier to the recycling rate of WEEE.

9.4 Levels of efficiency

Table 29: Levels of efficiency for EEE Measure 9

Indicator: % recycling rate of WEEE			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	40%	60%	40%

[527] Stubbings et al. (2021) Assessment of brominated flame retardants in a small mixed waste electronic and electrical equipment (WEEE) plastic recycling stream in the UK. Available at: link

Evidence RAG	Green	Red	Red

9.4.1 Current level of efficiency

Overall WEEE sent to recycling rates

The amount of WEEE sent for recycling is highly dependent on the collection rate. As with many other countries, the UK has struggled in recent years to achieve high collection rates, in part due to growing EEE quantities placed on the market being greater than WEEE arisings. However, the indefinite storage of used EEE by consumers, disposal in residual waste, recycling with scrap metal, informal and other unrecorded reuse and illegal export have also impacted negatively on the recorded collection rate. These alternative waste management routes contribute to the limited amount of WEEE sent for recycling.

It is notable that unreported EEE and WEEE accounts for a large proportion of WEEE in the UK. For instance, one report, with an IAS of 5, investigated the EEE and WEEE flows in the UK. It found that WEEE arisings in 2017 amounted to 1.5 million tonnes. Of this, 42% was treated and reported by AATFs, 24% was lost to the residual waste stream and 34% was likely to be treated or reused in some form but not reported to the administrator.[528]

Another study in the UK of EEE and WEEE flows investigated WEEE losses to various end-of-life treatment options, including AATFs, residual waste, theft and fire. The study concluded that the amount of WEEE sent for recycling (excluding losses) in 2017 was estimated at 53% of EEE placed on the market. This included WEEE sent to AATFs, light iron/scrap metal, legal export and T11 exemption.[529]

WEEE sent to recycling rates in other countries have also been reviewed. One study, with an IAS of 4, stated that only 17.4% of global WEEE is formally documented as being collected and recycled.[530] Two other studies quoted that the WEEE recycling rate in Europe is 30% [531] to 35%,[532] with the former exhibiting an IAS of 4, and the latter an IAS of 2. In France a figure of 36% was quoted as the proportion of WEEE screens that were sent to recycling facilities in 2017.[533] This study exhibits an IAS of 4. In the US, WEEE recycling rates have been recorded

528 Valpak (2018) UK EEE Flow 2018. Update Report. Available at: link
529 Material Focus (2020) Electrical Waste – Challenges and Opportunities: An Independent Study on Waste Electrical & Electronic Equipment (WEEE) Flows in the UK. Available at: link
530 Forti et al. (2020) The Global E-waste Monitor 2020: Quantities, flows, and the circular economy potential. Available at: link
531 Perchard, E. (2016) Trials to Improve Capture of Diminishing Raw Materials for Electrical Waste Under Way. Available at: link
532 Namias, J. (2013) The Future of Electronic Waste Recycling in the United Staes: Obstacles and Domestic Solutions. Available at: link
533 Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link

at 35%,[534] and in Japan, one source stated that 43% of discarded WEEE were transferred to recycling facilities.[535] Both sources exhibit an IAS of 4.

Recycling rates are, however, very product dependent. One source, with an IAS of 4, stated that, in the EU, only 10% of electronic devices are returned to the recycling process, however, it did not specify exactly which products came under the scope of this study.[536]

Product Category Recycling Rates

A number of studies reviewed focussed on specific product categories or product recycling rates, both in the UK and in other countries. When recycling rates were reported, it usually referred to the proportion, by weight, of the separately collected items per category that was sent for recycling.

One study based in the UK, with an IAS of 4, investigated WEEE recycling rates of specific product categories from AATFs.[537]

Table 30 below provides an overview of the findings from this study, compared with WEEE recycling targets set in the UK.

Table 30: UK AATF WEEE Recycling Targets and Reported Recycling Rates

Category	Recycling Target[538]	As reported by AATFs[539]
Large household appliances	80%	89%
Small household appliances	55%	72% (Small mixed WEEE)
IT and telecommunications equipment	70%	72% (Small mixed WEEE)
Consumer equipment	70%	72% (Small mixed WEEE)
Lighting equipment	55%	Not included in study
Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	55%	72% (Small mixed WEEE)

534 Babbitt and Althaf (2021) Mounting e-waste is harming the planet. Here's how we solve the problem. Available at: link
535 Tasaki et al. (2005) Effective assessment of Japanese recycling law for electrical home appliances: four years after the full enforcement of the law. Available at: link
536 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link
537 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link
538 Environmental Agency (2022) Waste electrical and electronic equipment (WEEE): evidence and national protocols guidance. Available at: link
539 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link

Category	Recycling Target[538]	As reported by AATFs[539]
Toys, leisure and sports equipment	55%	72% (Small mixed WEEE)
Medical devices (with the exception of all implanted and infected products)	55%	Not included in study
Monitoring and control instruments	55%	Not included in study
Automatic dispensers	80%	Not included in study
Display screens	70%	77%
Cooling appliances	80%	82% (Cooling equipment) 99% (Compressors)
Gas discharge lamps and LED light sources	80%	98% (Gas Discharge Lamps)
Photovoltaic panels	70%	Not included in study

Other sources also investigated specific product category sent to recycling rates. For examples two studies agreed that household appliance sent to recycling rates were high, at 88% [540] and 90%.[541] Both of these sources were specific to Europe and have an IAS of 4. It can therefore be assumed that the WEEE sent for recycling rate for household appliances is between 80 - 90%.

With reference to display equipment, one study, with an IAS of 5, quoted 82-85% sent to recycling rate for screens in France. This was calculated based on the quantity that was sent to recycling facilities compared to the amount of waste generated.[542] However, a second source, with an IAS of 4, quoted a television sent for recycling rate for the EU at a lower rate of 50%.[543] However, this figure included countries with lower recycling rates than are not comparable to the UK. As such, the figure referring to the French market is likely more applicable to the UK.

With reference to IT and telecommunications equipment, one study, with an IAS of 4, suggested that only 26% of computers and IT equipment are sent for recycling in the EU[544]. Another study estimated that 11% of obsolete computers are sent for recycling in the USA.[545] All of these sources exhibit and IAS of either 4 or 5. These figures are lower than the figures quoted in

540 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link
541 CECED (2017) Materials Flows of the Home Appliance Industry. Available at: link
542 Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
543 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link
544 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link
545 Herat, S. (2007) Sustainable Management of Electronic Waste (e-Waste). Available at: link

Table 30. For mobile phones, one source, with an IAS of 5, quoted that only 15% of mobile phones are sent for recycling in Europe.[546] One stakeholder during interviews stated that 40% of mobile phones in the UK and North America were sent for recycling.[547]

Finally, with reference to consumer equipment, one source, with an IAS of 4, stated that only 12% of electronic devices, such as phones, tablets and music players, and only 4% of video and sound equipment, are sent for recycling.[548] Again this is lower than the figures quoted in

Table 30.

One possible explanation for the difference in the WEEE sent for recycling rates between the literature and AATFs, is that the figures quoted by AATFs are only including the materials that are sent to the treatment facilities, rather than all WEEE generated, which literature sources are more likely to be including.

Material Recycling Rates

In general, literature sources and stakeholders during interviews agreed that the sent for recycling rates for most CRMs are very low. Sources agreed this is the situation in Europe [549] and the USA.[550] This is partly because these elements are present in WEEE in low quantities that it is not currently economically viable to recover them.[551] For example, a stakeholder during interviews highlighted that the sent for recycling rates for gallium and indium are 0%.[552] One study investigating screens sent for recycling in France, with an IAS of 5, found that the sent for recycling rates for copper, cobalt and other CRMs were 28%, 6% and 0%, respectively.[553]

However, other CRMs exhibit higher sent for recycling rates as they are known to be present in higher quantities in certain components. For example, PCBs have been at the forefront of recycling technological development, resulting in high recovery rates of palladium.[554] Another source stated that 97% of PCBs are sent for recycling, as reported by AATFs.[555] Similarly, another source, with an IAS of 4, stated that copper has a 95% reprocessing rate in the EU.[556]

With reference to precious metals, such as gold and silver, sent for recycling rates are reported to be slightly higher, with one source reporting between 30-50% global recovery of gold from

546 Sharifi and Shokouhyar (2021) Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach. Available at: link
547 Stakeholder interviews
548 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link
549 WEEE Forum (2021) Recycling Critical Metals in E-Waste: Make it the Law. Available at: link
550 O'Connor et al (2016) A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering. Available at: Link
551 European Environment Agency (2020) The case for increasing recycling: Estimating the potential for recycling in Europe. Available at: link
552 Stakeholder interviews
553 Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
554 WEEE Forum (2021) Recycling Critical Metals in E-Waste: Make it the Law. Available at: link
555 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link
556 Sarjas, A. (2018) Ecodesign of electronic devices. Available at: link

WEEE sources.[557] However, another source looking at Europe stated that less than 20% of gold was recovered from WEEE sources.[558] A French study investigating screens, with an IAS of 5, found that 23% of silver and 13% of gold was recovered from screens.[559]

For metals more generally, the reported rate of steel sent for recycling from AATFs was 90%, with the average metal recycling rate was 95% to 100%.[560] This is in line with input from one of the stakeholders, who stated that the metal sent for recycling rate is around 90%.

Finally, the sent for recycling rates for plastics, as reported by AATFs, is believed to be 50% for plastics from displays, and greater than 90% for non-hazardous plastics.[561] One stakeholder stated that the plastics sent for recycling rate is around 70%, with another stating that it may be less than 50%.[562]

POPs in WEEE Plastics

Persistent organic Pollutants (POPs), such as polybrominated diphenyl ethers (PBDEs), have been used extensively as flame retardants in the plastic components of EEE. However, the EU POPs Regulations sets a maximum concentration limit of 1,000 mg/kg for the total concentration of certain PBDEs in waste material. [563] When items containing POPs above this limit become waste, they must be treated in such a way that the POPs are destroyed or irreversibly transformed.

Although the use of most PBDEs in EEE was banned in 2007, POPs can still be present in WEEE since EEE manufactured before the restrictions will likely still be in use and becoming WEEE. Studies have shown that where POPs were used intentionally as flame retardants, levels of POPs could be as high 15-20 % (by weight) of the plastic material. [564] This same study highlighted that various categories of WEEE are likely to have POPs levels over the regulated thresholds.[565] Due to the risks of recycling POPs back into new products, the Environment Agency updated its waste classification guidance to state that all WEEE should be treated as containing hazardous substances (such as POPs) unless it can be proven that concentrations are below the regulated limits.[566] While there is technology that can detect and separate out POPs contaminated WEEE, it is an expensive process that is not currently widely adopted. As such, a large proportion of WEEE plastics are untreated as residual waste.

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557 Hagelüken and Corti (2010) Recycling of gold from electronics: Cost-effective use through 'Design for Recycling'. Available at: link
558 Hagelüken and Corti (2010) Recycling of gold from electronics: Cost-effective use through 'Design for Recycling'. Available at: link
559 Arudin et al. (2020) Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens. Available at: link
560 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link
561 Bond, M. (2022) The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme. Available at: link
562 Stakeholder interviews
563 Regulation (EU) 2019/1021 on Persistent Organic Pollutants. Available at: link
564 WRC (2020) An Assessment of the Levels of Persistent Organic Pollutants (POPs) in Waste Electronic and Electrical Equipment in England and Wales. Available at: link
565 WRC (2020) An Assessment of the Levels of Persistent Organic Pollutants (POPs) in Waste Electronic and Electrical Equipment in England and Wales. Available at: link
566 Environment Agency (2023) Classify different types of waste. Available at: link

Overall UK WEEE recycling rate

Whilst the literature review identified studies quantifying EEE and WEEE material flows in the UK and other countries, many of the studies only assessed the quantities of WEEE being sent to treatment facilities. Many of the studies did not then assess the quantities of material being sent for reprocessing or being recycled into new products, considering losses and rejected material at the treatment facilities. It is recognised that there are material losses at the AATFs and at subsequent material reprocessing stages, such as shredder residues, rejected WEEE plastics and other rejected non-target waste. AATFs reported varying recovery rates per product category, as noted in

Table 30. An average material loss rate of 20% (by weight) has therefore been applied, given the large amount of metal in large WEEE that provides an overall higher figure than that of the other categories. This implied an initial overall WEEE recycling rate of approximately 40%, with an amber RAG evidence rating.

In the workshop, four of the seventeen stakeholders voted on the current level of efficiency – consisting of two academics, one NGO and one thinktank. There was therefore moderate representation from the EEE sector. Of the four stakeholders that voted, all four voted for a current level of efficiency of 40%. Two of the votes were with high confidence and two were with medium confidence. One stakeholder asked for clarity as to what was defined as the recycling rate. Stakeholders were provided with the definition being the proportion of WEEE generated that is recycled into new products, considering losses and rejected material during the recycling process – i.e., not the collection rate of WEEE for recycling. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the current level of efficiency for Measure 9 is 40%, with a green RAG evidence rating. This increase from amber to green RAG evidence rating is based on consensus from stakeholders at the workshop, with medium and high confidence.

9.4.2 Maximum level of efficiency in 2035

The maximum recycling rate is largely reliant on the WEEE feedstock, as some WEEE may include large quantities of non-target material that cannot be recycled. One Chinese study modelled WEEE recycling, where a maximum recycling rate of 85% was applied.[567] Although it is not evident why this figure was chosen, it provides an indication of a perception of the maximum level of recycling achievable.

A number of pilot projects are in progress that are developing methods to extract high quantities of CRMs and other metals from WEEE. For example, one study found that it was possible to achieve a 90-92% recovery rate of magnesium from WEEE using dismantling and selective smelting or shredding and sorting process.[568] Another study in India reported a 97% recovery rate for metals using smelting and purification and a 95% selective recovery of copper

[567] Gu et al. (2016) Waste electrical and electronic equipment (WEEE) recycling for a sustainable resource supply in the electronics industry in China. Available at: link
[568] Fairphone (2017) How recyclable is the Fairphone 2? Available at: link

over precious metals using leaching.[569] Other studies have recovered over 99% of gold,[570] gold and copper,[571] and metals from PCBs [572] using various novel methods.

Although the recovery rate for metals has the potential to be increased, WEEE plastic degrade during the recycling process meaning that it cannot be technically possible to continuously recycle 100% of plastic material from WEEE.

These figures do not help to estimate an overall maximum recycling rate. However, given the ability to address the indefinite storage of used EEE by consumers, reduce disposal to residual waste, and improve other aspects of commercial waste recycling, the maximum recycling rate for WEEE was initially estimated at 60%, with a red RAG evidence rating.

In the workshop, four of the seventeen stakeholders voted on the maximum level of efficiency – consisting of two academics, one NGO and one thinktank. There was therefore moderate representation from the EEE sector. Of the four stakeholders that voted, three voted for a maximum level of efficiency by 2035 of above 60%, all with medium confidence. The remaining stakeholder voted for below 60%, with medium confidence. However, no quantified values were provided by stakeholders. Notably, the stakeholder that voted for below 60% mentioned that indefinite storage of used EEE by consumers would need to be considered. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the maximum level of efficiency by 2035 for Measure 9 is 60%, with a red RAG evidence rating. However, it is recognised that the level of efficiency may be higher. Despite this, the maximum level of efficiency has been retained at 60%. This is because stakeholders at the workshop did not provide a quantified estimate as to what extent this increase could be.

9.4.3 Business-as-usual in 2035

Participation from stakeholders indicated that metal recycling is already advanced and efficient. However, WEEE plastics pose a limiting factor due to the risks associated with POPs and other hazardous substances potentially present in WEEE plastic. There was general consensus that the current level of efficiency (estimated at 40%) would unlikely change without Government intervention. It was therefore initially estimated that the business-as-usual level of efficiency would remain at the current level of efficiency of 40%, with an amber RAG evidence rating.

In the workshop, five of the seventeen stakeholders voted on the business-as-usual level of efficiency – consisting of two academics, one social enterprise, one NGO and one thinktank. There was therefore moderate representation from the EEE sector. Of the five stakeholders that voted, four voted for a business-as-usual level of efficiency by 2035 of above 40%, all with medium confidence. However, no quantified value was provided by stakeholders. The

[569] Pathak et al. (2017) Assessment of legislation and practices for the sustainable management of waste electrical and electronic equipment. Available at: link
[570] Namias, J. (2013) The Future of Electronic Waste Recycling in the United Staes: Obstacles and Domestic Solutions. Available at: link
[571] Jiang et al. (2012) Improving the End-of-Life for Electronic Materials via Sustainable Recycling Methods. Available at: link
[572] Namias, J. (2013) The Future of Electronic Waste Recycling in the United Staes: Obstacles and Domestic Solutions. Available at: link

remaining stakeholder voted for 40%, with medium confidence. Based on the literature reviewed, stakeholder interview feedback and consensus from workshop stakeholders, the business-as-usual level of efficiency by 2035 for Measure 9 is 40%, with a red RAG evidence rating. The RAG evidence rating has been changed from amber to red due to conflicting estimates from the stakeholder interviews and workshop, with stakeholder interviews suggesting a level of efficiency of 40% and workshop stakeholders voting for a level of efficiency above 40%. As such, it is recognised that the level of efficiency may be higher. Despite this, the business-as-usual level of efficiency has been retained at 40%. This is because stakeholders at the workshop did not provide a quantified estimate as to what extent this increase could be.

10.0 Interdependencies

This report has discussed each of the Measures identified for the EEE sector and presented estimates for the maximum and business-as-usual level of efficiency they could achieve independently, that is, not considering any interdependencies or interactions between Measures.

However, in practice these Measures are likely to occur in tandem, and the levels of efficiency that are reached in each will depend on progress against other Measures. The precise nature of these interdependencies should be considered when using any of the level of efficiency estimates from this report in further research or modelling exercises that attempt to produce an estimate of the cumulative impact of these Measures over time.

A summary of the key interactions/interdependencies between the measures in this report with other Measures in the sector, and with Measures in other sectors is presented below. The key interdependencies for consideration are between Measure 5 (Repair and Refurbishment), Measure 7 (Direct Reuse) and Measure 8 (Remanufacture). Interdependencies for these Measures are based on the assumption that reusing, repairing, refurbishing or remanufacturing used EEE could likely result in the used EEE being unsuitable for further reuse, repair, refurbishment or remanufacture at its end-of-life phase. In other words, there are realistic maximum lifespans of EEE which would prevent used EEE from being reused, repaired, refurbished and/or remanufactured multiple times.

Note, the estimates for the current level of efficiency will by their nature reflect the interactions and interdependencies between Measures as they currently occur.

10.1 Interdependencies within the sector

Measures 1, 5, 7 and 8

- Measure 1 – Lightweighting of electrical and electronic equipment
- Measure 5 – Repair and refurbishment
- Measure 7 – Direct reuse
- Measure 8 – Remanufacture

Interdependencies for these Measures are based on lightweighting and reduced material use potentially reducing the durability and therefore reusability, repairability and/or ability to salvage parts for remanufacture.

Measures 5, 6 and 7

- Measure 5 – Repair and refurbishment

- Measure 7 – Direct reuse
- Measure 8 – Remanufacture

Interdependencies for these Measures are based on the assumption that reusing, repairing, refurbishing or remanufacturing used EEE could likely result in the used EEE being unsuitable for further reuse, repair, refurbishment or remanufacture at its end-of-life phase.

10.2 Interdependencies with other sectors

Incorporation of recycled content in place of virgin materials will likely have an impact on existing raw material producers in other sectors, namely the plastic, metal and glass sectors.

Glossary and abbreviations

AATFs	Approved authorised treatment facilities
ADISA	Asset Disposal and Information Security Alliance
B2B	Business to business
B2C	Business to consumer
CRM	Critical raw material
EEE	Electrical and electronic equipment
EPR	Extended producer responsibility
ESPR	Ecodesign Directive for Sustainable Products
HWRC	Household Waste and Recycling Centre
IAS	Indicative applicability score
ITAD	IT Asset Disposition
OEM	Original equipment manufacturer
PaaS	Product-as-a-Service
PC	Polycarbonate
PCB	Printed circuit board
PCR	Post consumer recycled
PEF	Polyethylene furanoate
PET	Polyethylene terephthalate
PIR	Post industrial recycled
POM	Placed on the market
POPs	Persistent Organic Pollutants
PVC	Polyvinyl chloride
PS	Polystyrene
PTT	Polytrimethylene terephthalate

REACH	Registration, evaluation and authorisation of chemicals
SME	Small and medium-sized enterprises
WEEE	Waste electrical and electronic equipment

Appendix A: IAS Scoring Parameters

Table 31: Methodology for the calculation of the IAS

Number of 'high' criteria	Number of 'low' criteria	IAS
Indifferent	3 or more	1
<= 1	2	2
>= 2	2	3
<= 2	1	3
>= 3	1	4
<= 1	None	3
2	None	4
>= 3	None	5

Table 32: IAS Scoring Parameters

Criteria	High	Medium	Low
Geography	**Specific to UK**	**Non-UK but applicable to the UK**	**Non-UK and not applicable to the UK**
Date of publication	< 10 years	10 to 20 years	> 20 years
Sector applicability	Sector and measure-specific, discusses resource efficiency and circularity	Sector and measure-specific, focus on decarbonisation	Cross-sector
Methodology	Research methodology well defined and deemed appropriate	Research methodology well defined but not deemed appropriate / Minor description of research methodology	No research methodology
Peer Review	Explicitly mentioned peer review	Not explicitly mentioned, but assumed to have been peer reviewed	Unknown

Appendix B: Search strings

- lightweight* AND (electr* OR [product category])
- (light weight* OR lightweight* OR lightweight*) AND electr*
- average weight AND (electr* OR [product category])
- (change OR increase OR decrease) AND weight AND (electr* OR [product category])
- ("recycled content" OR "recycled material" OR "recyclability") AND (electr* OR [product category])
- substitut* (electr* OR [product category])
- material substitution AND (electr* OR [product category])
- circular AND (electr* OR [product category]) AND design
- ("bio based" OR "bio-based") AND (electr* OR [product category])
- biogenic material AND (electr* OR [product category])
- disassembl* AND (electr* OR [product category])
- ("ecodesign" OR "eco design" OR "eco-design") AND (electr* OR [product category])
- electr* AND (alternative OR substitute) AND (circular* OR environment* OR resource efficien* OR sustainab*)
- (waste minimisation OR waste reduction OR waste prevention) AND (electr* OR [product category])
- lean manufacturing AND (electr* OR [product category])
- machinery efficiency AND (electr* OR [product category])
- machine yield AND (electr* OR [product category])
- manufactur* efficiency AND (electr* OR [product category])
- manufactur* AND waste minimisation AND (electr* OR [product category])
- manufactur* AND waste reduction AND (electr* OR [product category])
- electr* AND production efficien*
- circular economy AND (electr* OR [product category])
- circular economy business model AND (electr* OR [product category])
- rent* AND (electr* OR [product category])
- ("product as a service OR "product-as-a-service" OR PaaS) AND (electr* OR [product category])
- average AND (lifetime OR lifespan) AND (electr* OR [product category])
- repair AND (electr* OR [product category])

- subscription AND (electr* OR [product category])
- shar* AND (electr* OR [product category])
- leas* AND (electr* OR [product category])
- backmarket AND (electr* OR [product category])
- secondary market AND (electr* OR [product category])
- early obsolescence AND (electr* OR [product category])
- planned obsolescence AND (electr* OR [product category])
- premature obsolescence AND (electr* OR [product category])
- PLE AND (electr* OR [product category])
- lifetime extension AND (electr* OR [product category])
- electr* AND (reus* OR reprocess* OR re-process OR remanufactur* OR re-manufactur* OR remanufactur* OR re-manufactur* OR recla* OR post-consumer recycl*)
- circular design AND (electr* OR [product category])
- (durab* OR repair OR repairing OR repaired OR lifespan OR life-span OR life span OR extend OR modular) AND (electr* OR [product category])
- modular design AND (electr* OR [product category])
- ("second hand" OR "second-hand") AND (electr* OR [product category])
- recondition* AND (electr* OR [product category])
- recycling rate AND electr*
- remanufact* AND electr*
- resource recovery AND electr*
- refurbish* AND (electr* OR [product category])
- hoard* AND (electr* OR [product category])
- ("collection" OR "collection rate") AND (electr* OR [product category])
- material recovery AND (electr* OR [product category])
- critical raw material* AND (electr* OR [product category])
- CRM AND resource efficiency AND (electr* OR [product category])
- CRM AND recycling AND (electrical*)
- critical minerals (electr* OR [product category])
- asset management AND (electr* OR [product category])
- electr* AND (recycl* OR waste manag* OR closed-loop recycl* OR open-loop recycl*)
- sustain* AND electr*
- barriers AND sustain* AND (electr* OR [product category]

- drivers AND sustain* AND (electr* OR [product category])
- (resource efficiency OR material efficiency) AND (electr* OR [product category])
- optim* resource efficiency AND (electr* OR [product category])

Appendix C: Literature sources

The tables below list the literature sources for the EEE sector.

Table 33: List of literature sources for Measure 1.

Title	URL	Author	Year	IAS
Metal vs. Plastic: Which Is Better for Manufacturing	link	Accubrass	2021	3
iPhone 14 Pro Max - Technical Specifications	link	Apple	2023	5
iPhone 4 – Technical Specifications	link	Apple	2014	5
Mounting e-waste is harming the planet. Here’s how we solve the problem	link	Babbitt and Althaf	2021	3
What is Lightweighting and why is it important?	link	BOYD	2022	4
Materials Flows of the Home Appliance Industry	link	CECED	2017	4
7 Benefits of Lightweighting	link	Crawford, M.	2022	3
What Are the Benefits and Challenges of Lightweight Manufacturing?	link	Global Electronic Services Inc	2023	3
Why Are Laptops Getting Lighter and Slimmer?	link	Kanchwala, H.	2023	3
How Much Does a Laptop weigh? Updated 2023	link	Kenpachi, Z.	2023	3
Machine Design – Replacing Metal with Plastic	link	Kerns, J.	2017	4
8 benefits of lightweighting in manufacturing and engineering	link	nTop	2022	3
Persistent Organic Pollutants (POPs) in Plastics: Impact on WEEE Recycling	link	Priority Waste	2023	5

Title	URL	Author	Year	IAS
Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases	link	Rossi et al.	2020	4
Average size of LCD TV screens in the United States from 1997 to 2022	link	Statista	2023	3
Samsung Series 9 review (13-inch, mid-2012)	link	The Verge	2012	4
Electrical and electronic equipment (EEE): producer responsibilities	link	UK Government	2023	5
A hierarchical model for eco-design of consumer electronic products	link	Wang et al.	2015	3
Why TV screens are going extra large	link	Wired	2022	3

Table 34: List of literature sources for Measure 2.

Title	URL	Author	Year	IAS
War on plastic waste faces setback as cost of recycled material soars	link	Ambrose, J.	2019	3
Environmental Progress Report	link	Apple	2021	3
The eco-modulation of producers' financial obligations for WEEE in the UK	link	DSS	2022	4
Offer circular products and business solutions	link	Electrolux	2021	3
Defining Recyclate Quality Target Specification to Improve Plastic Packaging Circularity	link	Eunomia Research and Consulting	2023	3
Recycled plastic prices double as drinks makers battle for supplies	link	Evans, J.	2022	3
Comparative analysis of carbon emission from products of virgin plastics and recycled plastics and their environmental benefits	link	Ganesan, A.	2022	4

Title	URL	Author	Year	IAS
Closing the Plastics Circularity Gap: Full Report	link	Google and AFARA	2022	3
Post-consumer Recycled Plastics in Consumer Electronics Market Size, Share & Trends Analysis Report Byby Source (Non-bottle Rigid, Bottles), By Type, By Application (LCD Panels, Wearables), By Region, And Segment Forecasts, 2023 – 2033	link	Grand View Research	2023	5
Eco-design methodology for electrical and electronic equipment industry	link	Gurauskiene, I.	2006	3
Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics	link	Karvinen, H.	2015	5
Why Recycle Aluminium? | Novelis Recycling UK	link	Novelis Recycling UK	2023	3
ERP180 – Powerful, Sustainable Cleaning	link	Numatic	2023	3
Driving change: A circular economy for automotive plastic	link	Oakdene Hollines	2021	4
A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering	link	O'Connor et al.	2016	5
Plastic pollution is growing relentlessly as waste management and recycling fall short	link	OECD	2022	3
Recycled Content in Packaging: What you Need to Know	link	On the Edge	2021	3
Design for Recycling: Practical Guidelines for Designer. Guidelines for Electrical and Electronic Equipment	link	PolyCE	2021	4
Designing plastics circulation – electrical and electronic products	link	Raudaskoski et al.	2019	5
Circular economy indicators for organizations considering sustainability and business	link	Rossi et al.	2020	4

Title	URL	Author	Year	IAS
models: Plastic, textile and electro-electronic cases				
Supplemental Criteria for Electrical and Electronic Equipment	link	SCS Standards	2023	5
Tritan Renew	link	SMEG	2023	3
SORPLUS Recycled Plastic	link	Sony	2023	3
Guidance: Plastic packaging Tax: Steps to Take	link	UK Government	2021	3
Electronic Waste and the Circular Economy	link	UK Parliament	2020	4
High energy costs put plastic recycling 'at risk'	link	Vaclavova, B.	2022	3
Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective	link	Van Der Vegt et al.	2022	4
Metal Recycling Factsheet	link	EuRIC AISBL	N.D.	3

Table 35: List of literature sources for Measure 3.

Title	URL	Author	Year	IAS
Handbook of Bioplastics and Biocomposites Engineering Applications	link	Tariq Altalhi, I.	2022	5
Environmental Progress Report	link	Apple	2021	3
Future Trends in WEEE Composition and Treatment - A Review Report	link	Bacher et al.	2017	5
Waste is no longer a problem, it's a resource!	link	Beko	2023	4
Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management	link	Brix-Asala et al.	2018	4
The Truth About Bioplastics	link	Cho, R.	2017	5

Title	URL	Author	Year	IAS
The eco-modulation of producers' financial obligations for WEEE in the UK	link	DSS	2022	4
Applications for bioplastics	link	European Bioplastics	2023	5
Bio-based plastics play an essential role in the future circular plastics economy	link	European Bioplastics	2016	3
Fact Sheet: Bio-based plastics – fostering a resource efficient circular economy	link	European Bioplastics	2020	5
Are bioplastics more expensive than conventional petro-based plastics?	link	Institute of Bioplastics and Biocomposites	No Date	2
Life Cycle Assessment and Technical Performance of Recycled and Bio-based Plastics	link	Karvinen, H.	2015	5
The Potential Applications of Reinforced Bioplastics in Various Industries: A Review	link	Kong et al.	2023	5
Recycling of Bioplastics: Routes and Benefits	link	Lamberti et al.	2020	5
Life Cycle Impact Assessment of Polylactic Acid (PLA) Produced from Sugarcane in Thailand	link	Morao and Bie	2019	5
Recycled Content in Packaging: What you Need to Know	link	On the Edge	2021	3
Recycling of bioplastics, their blends and biocomposites: A review	link	Soroudi and Jakubowicz	2013	5
Estimated land use for bioplastics production worldwide from 2022 with a forecast to 2027.	link	Statista	2023	4
Sustainable sourcing of feedstocks for bioplastics: Clarifying sustainability aspects around feedstock use for the production of bioplastics	link	TotalEnergies Corbon	2022	4
Ring-Opening Polymerization of L-L Lactide: Kinetic and Modelling Study	link	Yu et al.	2009	5

Title	URL	Author	Year	IAS
Driving innovative products and solutions for a more sustainable future	link	Dell	N.D.	3

Table 36: List of literature sources for Measure 4.

Title	URL	Author	Year	IAS
Manufacturing Optimization for the Electronics Industry: How to Accelerate Product Development and Drive Engineering Efficiency with Instrumental Inc. on AWS	link	Amazon	2023	2
Environmental Progress Report	link	Apple	2021	3
How We Reduce Scrap Metal In the Injection Molding Process	link	Bennett Plastics	No date	3
Identifying design guidelines to meet the circular economy principles: A case study on electric and electronic equipment	link	Bovea and Perez-Belis	2018	4
Enablers, levers and benefits of Circular Economy in the Electrical and Electronic Equipment supply chain: a literature review	link	Bressanelli et al.	2021	4
How to improve operational efficiency in electronics manufacturing	link	Delta impact	2023	3
The Global E-waste Monitor 2020: Quantities, flows, and the circular economy potential	link	Forti et al.	2020	4
Recycling of copper from waste printed circuit boards by modified supercritical carbon dioxide combined with supercritical water pre-treatment	link	Golzary and Abdoli	2020	5
A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering	link	O'Connor et al.	2016	5
Facts and Figures about Materials, Waste and Recycling	link	United States Environmental Protection Agency (UNEP)	2023	3

Table 37: List of literature sources for Measure 5.

Title	URL	Author	Year	IAS
The potential of modular product design on repair behavior and user experience – Evidence from the smartphone industry	link	Amend et al.	2022	5
Helping you realise the full potential of sustainable returns solutions	link	AP Taylor	No Date	3
Growth of Interest for Refurbished Devices	link	Assurant	2021	3
Investigating sustainable consumer preferences for remanufactured electronic products	link	Aydin and Mansour	2023	5
Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain	link	Bovea et al.	2017	5
Materials Flows of the Home Appliance Industry	link	CECED	2017	4
Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom	link	Dindarian et al.	2012	5
Development of policy options for resource efficient eco-design of energy-related products	link	DSS	2022	4
The eco-modulation of producers’ financial obligations for WEEE in the UK	link	DSS	2022	4
Design products to be used more and for longer	link	Ellen MacArthur Foundation	2021	5
Proposal for a Directive on common rules promoting the repair of goods.	link	European Commission	2023	5
Europe’s consumption in a circular economy: the benefits of longer-lasting electronics	link	European Environment Agency	2023	5
Farnham Repair Café	link	Farnham Repair Café	2023	3

Title	URL	Author	Year	IAS
GAP Renew	link	GAP Group	2023	3
Money for old phones — but can the refurb boom last?	link	Gillet and Pratty	2022	3
A circular economy for smart devices	link	Green Alliance	2015	3
Ready steady grow: how the Treasury can mainstream circular business	link	Green Alliance	2023	4
Repair service convenience in a circular economy: The perspective of customers and repair companies.	link	Güsser-Fachbach et al.	2023	5
What We Do: GXO ServiceTech	link	GXO ServiceTech	2023	4
Living Progress Report 2019	link	Hewlett Packard	2019	5
Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study.	link	Hischier and Böni	2021	5
Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. A Report of the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya	link	IRP	2018	5
Integration of Circular Economy Principles in Consumer Behaviour for Electrical and Electronic Equipment	link	Istudor et al.	2023	4
Refurbished technology gains popularity as a cost-saving choice.	link	Kantar Group	2023	5
International Trade in second-hand electronic goods and the resulting global rebound effect.	link	Krings, H.	2015	5
If It Is Broken, You Should Not Fix It: The Threat Fair Repair Legislation Poses to the Manufacturer and the Consumer	link	MacAneney, M.	2018	5
HPE refurbishes legacy IT assets to make money for users.	link	McKenna, B.	2019	3

Title	URL	Author	Year	IAS
Refurbished Electronics Market: Global Industry Analysis and Forecast (2023-2029)	link	MMR	2023	3
A Study of the Potential of VRPs for Resource Efficiency.	link	Oakdene Hollins	2022	4
Is a sustainable electronics industry possible?	link	Rawnsley, J.	2023	3
The French repair index: challenges and opportunities.	link	Right to Repair	2021	5
Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach	link	Sharifi and Shokouhyar	2021	5
Circular IT Management in Practice	link	TCO Certified	2020	4
The Ecodesign for Energy-Related Products and Energy Information Regulations 2021. Available at: link	link	UK Government	2021	5
Electronic Waste and the Circular Economy	link	UK Parliament	2020	5
Paving the way towards circular consumption	link	Weelden et al.	2016	5
Poorest Countries in Europe.	link	Wisevoter	2023	4

Table 38: List of literature sources for Measure 6.

Title	URL	Author	Year	IAS
Sustainable Technology Lifecycle Management	link	3StepIT	No Date	3
Master Circular Business with the Value Hill	link	Achterberg, E.	2016	3
Should You Lease or Buy Your Tech Equipment?	link	Alexander, P.	2005	2
Lease, Don't Buy, Capital Equipment	link	Business Owner's Playbook	2023	3
A circular economy for smart devices	link	Green Alliance	2015	3

Title	URL	Author	Year	IAS
Ready steady grow: how the Treasury can mainstream circular business	link	Green Alliance	2023	4
Integration Of Circular Economy Principles In Consumer Behaviour For Electrical And Electronic Equipment	link	Istudor et al.	2023	4
The Product as a Service Business Model: Performance over Ownership. Waste to Wealth	link	Lacy and Rutqvist	2015	5
Rental Solutions	link	Miele	2023	3
Leasing solutions	link	Numatic	2023	3
Behavioral change for the circular economy: A review with focus on electronic waste management in the EU	link	Parajuly et al.	2020	5
Student Opinion: Reuse and rental of electronic equipment	link	Students Organising for Sustainability	2019	4
A scoping review of design for circularity in the electrical and electronics industry	link	Suppipat and Hu	2022	5
Tool Hire	link	Travis Perkins	2023	3
2018 Corporate Social Responsibility Report	link	Xerox	2018	3

Table 39: List of literature sources for Measure 7.

Title	URL	Author	Year	IAS
Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens	link	Arduin et al.	2020	5
Growth of Interest for Refurbished Devices	link	Assurant	2021	3
The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme	link	Bond, M.	2022	4

Title	URL	Author	Year	IAS
Potential reuse of small household waste electrical and electronic equipment: Methodology and case study	link	Bovea et al.	2016	5
A survey on consumers' attitude towards storing and end of life strategies of small information and communication technology devices in Spain	link	Bovea et al.	2018	5
Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain	link	Bovea et al.	2017	5
Identifying the impact of the circular economy on the Fast-Moving Consumer Goods Industry: Opportunities and challenges for businesses, workers and consumers – mobile phones as an example	link	Centre for European Policy Studies (CEPS)	2019	4
Towards a Circular Economy: Exploring Routes to Reuse for Discarded Electrical and Electronic Equipment	link	Cole et al.	2017	5
Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom	link	Dindarian et al.	2012	4
The eco-modulation of producers' financial obligations for WEEE in the UK	link	DuPont Sustainable Solutions (DSS)	2022	4
Second-Hand Tech: Could 2023 Be A Tipping Point For E-Waste?	link	George, S.	2023	3
Money for old phones — but can the refurb boom last?	link	Gillet and Pratty	2022	3
A circular economy for smart devices	link	Green Alliance	2015	3
Ready steady grow: how the Treasury can mainstream circular business	link	Green Alliance	2023	4
Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study.	link	Hischier and Böni	2021	5

Title	URL	Author	Year	IAS
Integration of Circular Economy Principals in Consumer Behaviour for Electrical and Electronic Equipment	link	Istudor et al.	2023	5
Business Electrical Waste: Challenges and Opportunities	link	Material Focus	2022	4
Electrical waste – challenges and opportunities	link	Material Focus	2020	5
39 million tech items are hoarded in UK homes including £1.5 billion worth of working laptops that could be resold.	link	Material Focus	2022	5
7.5 million unused electrical toys gathering dust in UK homes.	link	Material Focus	2023	5
Behavioral change for the circular economy: A review with focus on electronic waste management in the EU	link	Parajuly et al.	2020	5
Consumer attitude towards the repair and the second-hand purchase of small household electrical and electronic equipment. A Spanish case study	link	Perez-Belis et al.	2017	5
Student Opinion: Reuse and rental of electronic equipment	link	Students Organising for Sustainability	2019	4
Vinted Climate Change Impact Report 2021.	link	Vaayu	2021	3
Switched on to value: Powering business change	link	WRAP	2017	5
Realising the Reuse Value of Household WEEE	link	WRAP	2011	5

Table 40: List of literature sources for Measure 8.

Title	URL	Author	Year	IAS
Remanufacturing of Industrial Electronics: A Case Study from the GCC Region	link	Alkouh et al.	2023	5

Title	URL	Author	Year	IAS
Investigating sustainable consumer preferences for remanufactured electronic products	link	Aydin and Mansour	2023	5
British Standards Institute	link	British Standards Institute	2010	5
Sustainable IT: What's the difference between Remanufactured and Refurbished?	link	Canon Europe	2023	3
We Help Companies Decarbonise Their IT Estate	link	Circular Computing	2023	3
Electronic product returns and potential reuse opportunities: a microwave case study in the United Kingdom	link	Dindarian et al.	2012	5
Contribution of remanufacturing to Circular Economy	link	European Environment Agency	2018	5
Exploring the pursuit of sustainability in reverse supply chains for electronics	link	Flygansvaer et al.	2018	5
Remanufacturing and Product Design	link	Gray and Charter	2008	3
A circular economy for smart devices	link	Green Alliance	2015	3
Design for remanufacturing in China: a case study of electrical and electronic equipment	link	Hatcher et al.	2013	5
Combining environmental and economic factors to evaluate the reuse of electrical and electronic equipment – a Swiss case study.	link	Hischier and Böni	2021	5
Consumer Electronics Stores in the US	link	IBISWorld	2022	4
Application of active disassembly to extend profitable remanufacturing in small electrical and electronic products	link	Ijomah and Chiodo	2010	5
Re-defining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy. A Report of the International	link	IRP	2018	5

Title	URL	Author	Year	IAS
Resource Panel. United Nations Environment Programme, Nairobi, Kenya				
Electronics Remanufacturing Explained	link	LightGuide	2022	3
Technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China	link	Lonf et al.	2016	5
US Electronics & Appliance Stores Market Size	link	Mordor Intelligence	2023	4
Overview of Prospects in Adopting Remanufacturing of End-of-Life Electronic Products in the Developing Countries	link	Nnorom and Osibanjo	2010	3
Remanufacturing Market Study. For Horizon 2020, November 2015	link	Parker et al.	2015	5
UK remanufacturing worth £5.6bn if business model can be cracked	link	Perella, M.	2014	3
Reverse remanufacturing of electrical and electronic equipment and the circular economy	link	Romero de Brito et al.	2022	4
Waste Electrical and Electronic Equipment versus End of Life Vehicles: A State of the Art Analysis and Quantification of Potential Profits	link	Rosa and Terzi	2016	5
Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach	link	Sharifi and Shokouhyar	2021	5
Consumer Electronics - United States	link	Statista	2023	4
The Waste Electrical and Electronic Equipment Regulations 2013	link	UK Government	2013	5
Saving You Money	link	Whirlpool	2023	3
2018 Corporate Social Responsibility Report	link	Xerox	2018	3
Sustainability Assessment of Electronic Waste Remanufacturing: The Case of Laptop	link	Yuksek et al.	2023	5

Title	URL	Author	Year	IAS
Remanufacturing strategies: A solution for WEEE problem	link	Zlamparet et al.	2017	5

Table 41: List of literature sources for Measure 9.

Title	URL	Author	Year	IAS
Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE: Focus on screens	link	Arduin et al.	2020	5
Mounting e-waste is harming the planet. Here's how we solve the problem	link	Babbitt and Althaf	2021	3
Environmental and economic trade-offs in consumer electronic products recycling: a case study of cell phones and computers	link	Bhuie et al.	2004	5
The Carbon Footprint of WEEE (Waste Electronic and Electrical Equipment) in the UK – a case study based on the UK's largest WEEE producer compliance scheme	link	Bond, M.	2022	4
Sustainability Tensions in Supply Chains: A Case Study of Paradoxes and Their Management	link	Brix-Asala et al.	2018	4
Materials Flows of the Home Appliance Industry	link	CECED	2017	4
The eco-modulation of producers' financial obligations for WEEE in the UK	link	DuPont Sustainable Solutions (DSS)	2022	4
Classify different types of waste	link	Environment Agency	2023	5
Electrical waste: retailer and distributor responsibilities	link	Environment Agency	2023	5
Waste electrical and electronic equipment (WEEE): evidence and national protocols guidance	link	Environment Agency	2022	5

Title	URL	Author	Year	IAS
Procuring for: Repair, Re-use and Remanufacturing	link	Eunomia Research & Consulting	2016	4
The case for increasing recycling: Estimating the potential for recycling in Europe	link	European Environment Agency	2020	5
Regulation (EU) 2019/1021 on Persistent Organic Pollutants	link	European Parliament	2019	5
How recyclable is the Fairphone 2?	link	Fairphone	2017	4
The Global E-waste Monitor 2020: Quantities, flows, and the circular economy potential	link	Forti et al.	2020	4
How sustainable is the Fairphone 2? Results of an expert survey	link	Fraunhofer IZM	2016	4
Waste electrical and electronic equipment (WEEE) recycling for a sustainable resource supply in the electronics industry in China	link	Gu et al.	2016	4
Recycling of gold from electronics: Cost-effective use through 'Design for Recycling'	link	Hagelüken and Corti	2010	4
Sustainable Management of Electronic Waste (e-Waste)	link	Herat, S.	2007	5
Improving the End-of-Life for Electronic Materials via Sustainable Recycling Methods	link	Jiang et al.	2012	3
Technical solutions to improve global sustainable management of waste electrical and electronic equipment (WEEE) in the EU and China	link	Lonf et al.	2016	5
Salvaged Gold & Silver	link	Lylie	2023	3
Electrical waste – challenges and opportunities	link	Material Focus	2020	5
Update to A Review (Economic and Environmental) of Kerbside Collections for Waste Electricals. Final Report.	link	Material Focus	2022	5

Title	URL	Author	Year	IAS
The Future of Electronic Waste Recycling in the United States: Obstacles and Domestic Solutions	link	Namias, J.	2013	3
A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering	link	O'Connor et al.	2016	5
Assessment of legislation and practices for the sustainable management of waste electrical and electronic equipment	link	Pathak et al.	2017	4
Trials to Improve Capture of Diminishing Raw Materials for Electrical Waste Under Way	link	Perchard, E.	2016	4
Sustainable jewellery – the beauty of recycling	link	Recycle Your Electricals	2023	3
Critical raw materials in waste electrical and electronic equipment	link	Royal Society of Chemistry	2019	4
Ecodesign of electronic devices	link	Sarjas, A.	2018	4
Challenges to the European automotive industry in securing critical raw materials for electric mobility: the case of rare earths	link	Schmid, M.	2020	4
Promoting consumer's attitude toward refurbished mobile phones: A social media analytics approach	link	Sharifi and Shokouhyar	2021	5
Assessment of brominated flame retardants in a small mixed waste electronic and electrical equipment (WEEE) plastic recycling stream in the UK.	link	Stubbings et al.	2021	5
Biodegradable electronics: cornerstone for sustainable electronics and transient applications	link	Tan et al.	2016	5
Effective assessment of Japanese recycling law for electrical home appliances: four years after the full enforcement of the law	link	Tasaki et al.	2005	4
Circular IT Management in Practice	link	TCO Certified	2020	4
Precious Metal Recovery from Electronic Waste	link	The Royal Mint	2023	3

Title	URL	Author	Year	IAS
The Waste Electrical and Electronic Equipment Regulations 2013	link	UK Government	2013	5
Electronic Waste and the Circular Economy	link	UK Parliament	2020	4
Excellence in recycling	link	Unicore	2023	3
UK EEE Flow 2018. Update Report	link	Valpak	2018	5
Recycling Critical Metals in E-Waste: Make it the Law	link	WEEE Forum	2021	3
An Assessment of the Levels of Persistent Organic Pollutants (POPs) in Waste Electronic and Electrical Equipment in England and Wales	link	WRC	2020	5

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