RESOURCE EFFICIENCY OF ELECTRICAL APPLIANCES IN UK HOUSEHOLDS: CAN CONSUMER EDUCATION HELP CUT COSTS AMID THE COST-OF-LIVING CRISIS?

Margo Reynolds, Nellie Salter, Żaneta Muranko, Emily Easman, Fiona Charnley, Ryan Nolan, Halid Abu-Bakar, Peter Hopkinson
UKRI CE-Hub, University of Exeter Business School

A collaboration with the Association of Manufacturers of Domestic Electrical Appliances

May 2023

CE-HUB
UKRI National Interdisciplinary Circular Economy Research

AMDEA
The Association of Manufacturers of Domestic Appliances

University of Exeter Business School

Contents

Executive summary

Background

Over the last few years, efforts have been made in the UK to reduce the environmental impact of domestic electrical appliances. Domestic electrical appliances are made of various materials including steel, polymers and precious metals, and use energy and water to function. Industrial organisations recognise the need to reduce the environmental impacts across the supply chain, from material sourcing, through manufacture, use and disposal, with the use phase representing a significant portion of the environmental impacts. For example, as much as 73-93% of the overall lifecycle carbon emissions of a washing machine occur in the use phase alone (Alejandre, Akizu-Gardoki and Lizundia, 2022). There have been technological improvements in recent years focusing on energy and resource efficiency of electrical domestic appliances. Nonetheless, the technical capabilities of appliances to reduce the use of energy or water at home still depends on consumer behaviour in the context of their daily interaction with appliances (Hueppe et al., 2021). The consumer knowledge about how to interact with appliances in order to enable resource efficiency is key to informing their resource efficiency behaviours, however this knowledge remains low which highlights a need for consumer education (Brounen et al., 2013). Furthermore, the cost-of-living crisis combined with post-COVID-19 social and economic recovery, as well as new hybrid home and workplace working arrangements have disrupted household routines and instigated new behaviours at home.

This study seeks to understand consumer appliance use and care behaviours in the context of the cost-of-living crisis, post-COVID-19. Specifically, the study attempts to address low levels of consumer knowledge about resource efficiency related to appliance use by testing how consumer education can drive resource efficiency at home. The study views resource use through the lens of the circular economy, which attempts to keep materials in use at their highest value to reduce environmental impact. In addition to energy and water, resource use includes the materials that construct each appliance. Consequently, maintenance and repair activities are considered as contributors to resource efficiency since they help to keep appliances in use for as long as possible.

Method

This study was carried out in seven households in Southwark Borough in London, forming an in-depth understanding of consumer routines involving domestic appliances; these include laundering, cooking, and boiling water. Qualitative and quantitative data was collected through online surveys, in-person observations and semi-structured interviews. The focal behavioural model employed was the COM-B model, which categorises behaviour into three components: capability, opportunity, and motivation (Michie et al., 2014).

Key Findings

The study uncovered the following findings in the areas of energy use, product life extension and education:

Energy use

- Over a third of households reported that saving energy was their main motivating factor for choosing energy saving options (e.g., appliance settings) when using their appliances. Saving money (reported by 28%) and saving the planet (19%) were also major motivators, along with mitigating climate change (14%), and both increasing time efficiency and saving water (1.5%).
- New technology (i.e., smart appliances) and eco-settings alone are not enough to ensure energy efficient behaviours. Consumer education is needed, and the power of deeply established routines needs to be accounted for.
- Consumers rarely explore appliance settings, and therefore miss out on energy efficient options; the use of eco-settings occurs more frequently when combined with education.
- There is a potential for considerable energy and cost savings across individual households if energy efficient behaviours are practiced across all appliances at home.

Product-life extension

- Consumers are motivated to repair their appliances, primarily to save money and reduce waste.
- Consumer knowledge of product life extension practice, especially maintenance and repair, is low but can be increased significantly through tailored consumer education.
- Consumer education helps to solidify the link between maintenance activities and product life extension.

Effects of education

- Consumer education influenced each participant of the study to perform on average as many as 22 unique resource efficiency behaviours, with over a third being new behaviours learnt primarily through the intervention (i.e., consumer education) administered in this study.
- Specifically, 38% of all recommended energy efficiency behaviours, and 25% of all recommended maintenance behaviours, were newly taken up across the households and for various appliances after participants were exposed to consumer education.
- The presence of the action-intention gap in many resource efficiency behaviours demonstrates that consumers still face many barriers to efficient energy use, maintenance, and repair behaviours.

Summary of Recommendations

In summary the following recommendations are made to industrial stakeholders across the value chain, including UK businesses and policymakers:

- Education can be used to improve behavioural intention of the consumer and influence action. At the same time, it is important to understand other barriers to performing resource efficiency behaviours that consumers face, which can be associated with their unique individual daily routines and other macro-level external factors.
- Appliance design and consumer education need to be aligned to increase the uptake of resource efficient behaviours.
- There is an opportunity for industry to build relationships with the consumers that foster trust and loyalty beyond the point of purchase through maintenance and repair education.

- There is a need for improving consumer education about energy efficiency and product life extension, which includes varying communication channels and standardised content.
- Smart technology can be an enabler for energy efficiency and maintenance but is not in itself enough to guarantee resource efficiency. Smart technology can pose a problem for appliance repairability.

Conclusions

This research is important for industrial organisations, including UK businesses and policymakers as it helps bring understanding of the various ways UK consumers contribute to the environmental impacts of the domestic electrical appliance industry. With this understanding, industrial stakeholders, UK businesses and policymakers can incorporate more behavioural knowledge into an offering and appliance design to ensure resource efficiency is optimal and appliances can stay in use for as long as possible. The research also shows that consumer education is integral to resource efficiency and should be a strong focus in the future. With more than 27% of home energy used to power major appliances (Energy Savings Trust, 2022), industry collaboration can play a key role in achieving Net Zero homes.

Keywords

Household behaviour, consumer education, energy efficiency, product life extension, domestic electrical appliances

1.0 Introduction

1.1 Background

1.1.1. The UK Cost-of-Living Crisis

The cost-of-living crisis in the UK refers to the situation where the prices of essential goods and services are rising at a faster rate than people's incomes, making it harder for them to afford basic needs such as housing, food, and utilities (Harari et al., 2023). This has been a major concern in the UK, particularly for those on low incomes. There are several factors contributing to the cost-of-living crisis in the UK, including the rising cost of housing, energy prices, and food prices, as well as stagnant wages and cuts to public services. The COVID-19 pandemic has exacerbated the situation, with many people losing their jobs or experiencing reduced hours, while the prices of essential goods and services continue to rise. The impacts of the cost of living can be severe, particularly for those on low incomes, as they may struggle to afford basic needs.

Inflation has also had a significant impact on the cost of living for the average UK household with the Consumer Price Index inflation rate rising from 5.1% in November 2021, the highest it had been in almost a decade to 11.1% in October 2022, a 41-year high (ONS, 2022a; Harari et al., 2023). This increase in inflation has led to higher prices for goods and services across the board, including food, energy, housing, and transportation, thus impacting the cost of living for UK households. As a result, many households in the UK have had to change their behaviour in response to the changing economic environment, with many having to cut back on spending, focusing on essential goods and services. Many households had to reduce their energy consumption and switch to alternative products or brands or postpone purchases until prices or availability improve (ONS, 2022b, 2023).

Several factors, including, the COVID-19 pandemic, increased demand for electronics, and supply chain disruptions, have resulted in material supply issues for products like electrical appliances. Disruptions to global supply chains during the pandemic with factory closures, transportation restrictions, and labour shortages have all contributed to delays and shortages in the supply of materials. The pandemic also led to increased demand for electronics, as more people are working and studying from home, which has put additional strain on supply chains and made it harder to secure materials. In addition, due to rising energy costs, manufacturers have needed to increase their prices to cover energy intensive production and transportation. These factors have led to significant increases in the costs of energy and availability of goods and services, ultimately affecting UK household consumption (DESNZ and BEIS, 2023).

In September 2022, the UK government announced a cap on energy tariffs, bringing the typical household energy bill to about £2500 per year, a staggering increase from the annual energy bills of previous years (BEIS, 2023). The government also rolled out several additional payment packages to manage household costs, including a £400 subsidy to energy bills for every UK household for the winter months in 2022/23 (BEIS, 2023; Harari et al., 2023). Nonetheless, in March 2023, as much as 93% of adults in the UK reported an increase to their daily living costs and 63% have changed their spending behaviour as a result. Additionally, over half of UK adults reported using less fuel (gas or electricity) in their homes (ONS, 2023).

The average cost of household electrical appliances in the UK has been increasing, in part due to the rising cost of raw materials, such as steel and copper (Statista, 2022).

Ultimately, the purchase or replacement of essential household appliances has been difficult for many UK households. A recent study by turn2US, the UK poverty charity, revealed that millions across the UK are living without household essentials. As many as 1.9 million people living without a cooker (i.e., combined oven and stovetop), one in ten without a freezer, one in thirty without a fridge, and one in twenty without a washing machine (Turn2us, 2020). As a result, there are many disadvantaged UK households, including families and individuals affected by complex physical and mental needs, who are living without essential appliances.

1.1.2. UK Household Electrical Appliance Market

Electrical appliances are important and essential in supporting the daily routines of UK households. They play an important role in making homes more comfortable, convenient, and safe. The market for household electric appliances in the UK is large and competitive, with businesses focusing on innovation, energy efficiency, and sustainability. This includes a wide range of appliances, including refrigerators, washing machines, dishwashers, ovens, vacuum cleaners, and small appliances, such as toasters and kettles. The major market players include global brands competing alongside well-established UK brands. Revenue from household appliances in the UK is predicted to amount to approximately £8.1 billion in 2023 and is projected to grow annually by 3.6% until 2028 (Statista, 2023a). In 2020 alone, over 16 million large appliances and over 66 million small appliances were sold to UK consumers, reaching a cumulative value of £4.6 billion and £3.4 billion respectively (AMDEA, 2021). Over 98% of UK households have a fridge or fridge/freezer, 88% a washing machine and 44% a dishwasher, with consumers reportedly keeping their large appliances in use for ten to fifteen years before disposal (AMDEA, 2021a).

The growth of the market is driven by several factors, including technological advancements, changing consumer behaviour, and increasing awareness of energy efficiency and sustainability. For example, there has been a shift towards connected appliances that can be controlled remotely through smartphones or voice assistants. Additionally, there is a growing demand for energy-efficient appliances that can help consumers save money on their energy bills and reduce their carbon footprint (BEIS, 2019).

1.1.3. Reducing daily resource consumption through energy efficiency

Energy efficiency refers to reduced energy intensity, meaning less energy use per activity output, and increased energy productivity, referring to higher activity output per energy input (Stern, 2014). An energy efficient appliance is designed to function using less electricity or gas compared to other appliances, without sacrificing performance, whereas energy efficient behaviour refers to actions taken by an individual or collectives (e.g., household occupants) to reduce energy consumption or increase the efficiency of energy use (Stern, 2014). A combination of energy efficient technology and consumer behaviour can bring several benefits including reduced energy bills, a smaller carbon footprint, and increased energy security.

Households use one fifth of global energy supply (Brounen, Kok and Quigley, 2013). In the UK specifically, total household energy use accounts for 32% of the country's overall energy consumption (Statista, 2023b). Space heating is the greatest source of energy use accounting for 76% of the total energy consumption in UK households (BEIS, 2020). While refrigeration and laundry appliances account for 27% of UK domestic energy use (Energy Savings Trust, 2022).

The literature on household energy efficiency in the context of electric appliances is vast

and continues to grow. This is driven by concerns about the environmental impact of energy consumption, as well as the rising cost of energy for households. Many studies have focused on identifying the factors that influence household energy consumption, such as the consumer behaviour and appliance efficiency.

Literature also explores factors that contribute to consumer decisions to purchase energy efficient heating appliances such as demographics, household income, consumer engagement, co-benefits, aesthetics and 'heritage values' (Galvin and Sunikka-Blank, 2013). Results from these studies show that consumer awareness, literacy, and behaviour around their own energy consumption is low (Brounen, Kok and Quigley, 2013). However, household behaviours can have a significant effect on energy use and are as important as material and design in some cases (Trotta, 2018). Accordingly, improvements to resource efficiency in household appliance use need to focus on both appliance design, the consumer, and their interactions.

In terms of appliance design, manufacturers and policymakers have focussed on improving energy and water efficiency in domestic household appliances for several years. For example, in a ten-year period, manufacturers improved the average washing machine so that it uses 30% less energy and water (Pakula and Stamminger, 2010). New energy efficiency labelling regulations were introduced in the EU and UK in 2021 (DESNZ and OPSS, 2021; European Commission, 2021) to improve energy rating scales, as most appliances were crowded at the top of the scale, resulting in the re-scaling of energy labels from A+++ to G to A to G energy rating classes (AMDEA, 2021b). This aims to provide clear and consistent information to consumers to support informed purchasing decisions and encourage competition between manufacturers in relation to improving energy efficiency (DESNZ and OPSS, 2021). Manufacturers have also introduced new smart-technology in appliances to help reduce energy consumption, encourage regular maintenance, and understand how appliances are used in homes. Recent UK eco-design legislation has also ensured that certain appliances (i.e., dishwashers, washing machines) have eco-settings as their default to help consumers choose these settings more regularly (legislation.gov.uk, 2021). Together these changes represent significant improvements to energy efficiency and have contributed to lower energy consumption in UK households today.

However, design improvements alone are only one piece of the puzzle; consumer behaviour is also a key element for ensuring energy efficiency in appliance use. A study carried out in the UK in 2014 critically examines government policy and producer approaches that lean too heavily on technological solutions for improving energy efficiency. The study shows that this approach overlooks the significance of how users interact with new technology, and how their consumption of energy is embedded in established routines (Ozaki and Shaw, 2014). Other studies show that consumer behaviour can account for more than a third of energy consumption in certain appliances, and the introduction of new 'best practice' can reduce this by 52% (Hueppe et al., 2021). Understanding how new technologies fit into existing routines and household norms can help manufacturers and policymakers increase adoption of intended energy efficient behaviours (Ozaki and Shaw, 2014).

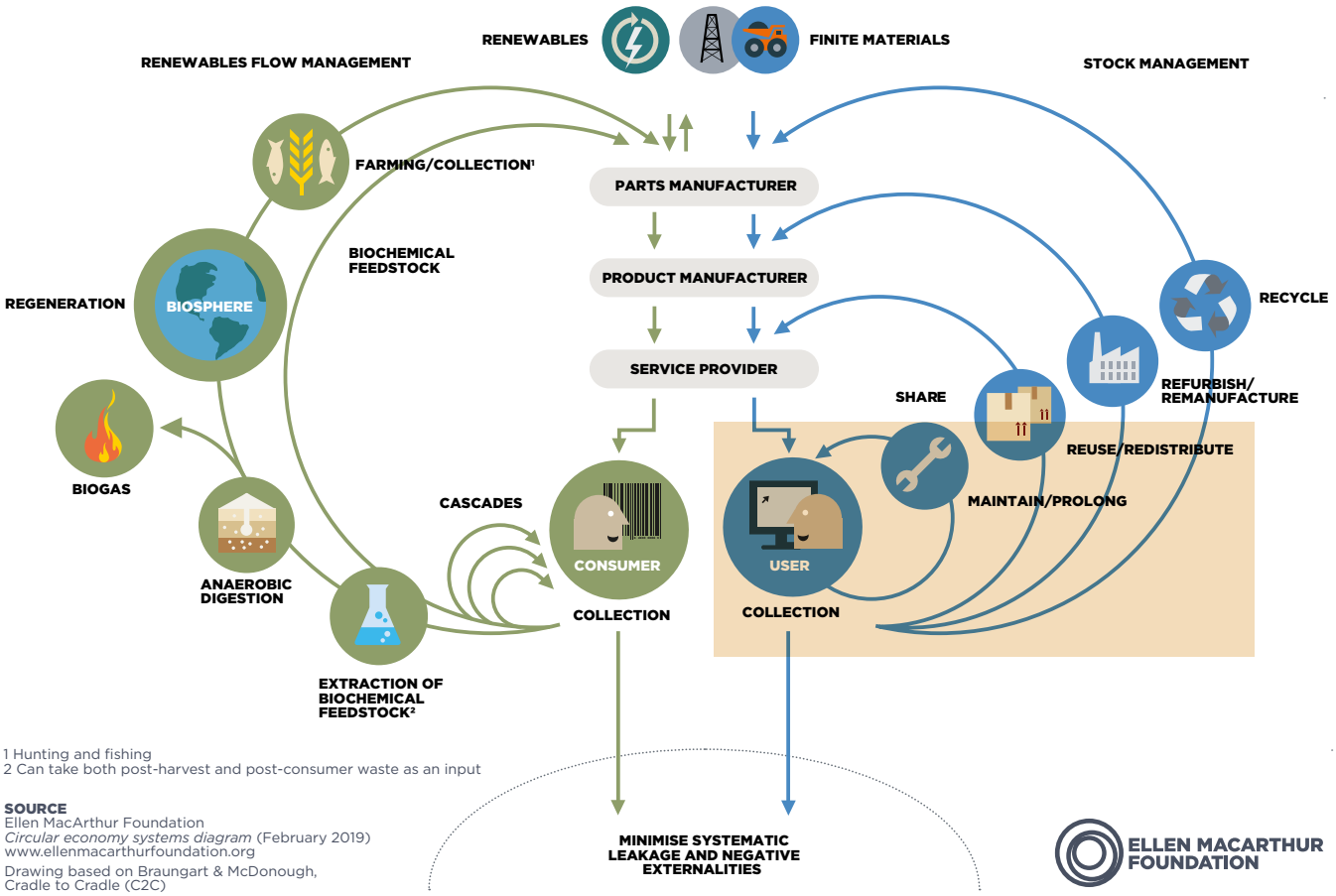
In addition to design improvements, consumer behaviour around older appliances must be considered because older appliances are still used in many UK homes due to high replacement costs. In these cases,

technological limits to energy efficiency must be compensated by consumer behaviour. However, low literacy rates in personal and household energy use imply that consumer education is needed to improve energy efficient behaviours.

1.1.4. Reducing Recurring Acquisition Through Product Life Extension

Circular economy is an industrial-economic model built to facilitate a closed flow of resources in the system where waste is minimised, and resources are kept in use for as long as possible. Product life extension is a process that aims to prolong the lifespan of a product and is a key element of a circular economy (Kirchherr, Reike and Hekkert, 2017). Product life extension involves consumers (or other actors) undertaking processes such as maintenance and repair to ensure products can be kept in use for as long as possible (see Fig. 1 below), reducing the use of virgin materials and energy that would otherwise be required to produce new products, ultimately reducing environmental and societal impacts associated with production and consumption. It is also one of the most effective environmental strategies because of its potential to slow down consumption cycles (Cooper and Christer, 2010).

Figure 1. The butterfly diagram from the Ellen MacArthur Foundation locates product life extension among other



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough, Cradle to Cradle (C2C)

There are many reasons consumers deem a product to be obsolete and thus need to be discarded (Zeeuw van der Laan and Aurisicchio, 2019). Reasons can be either relative or absolute forms of obsolescence (see Table 1 below), which require different solutions from various parties, including consumers, organisations, and industry (Laitala et al., 2021).

Table 1. Types of Obsolescence (adapted from Zeeuw van der Laan and Aurisicchio, 2019).

Types of Obsolescence	Causes
Relative	
Aesthetic	Changes in appearance of resources, e.g., fading, dirty, worn out, making the product less desirable. Loss of cosmetic and decorative value. When a product is found to be out of fashion.
Societal	Societal changes that impact needs. Legislation that sparks behavioural changes.
Economic	When (up)keeping products becomes too costly e.g., maintenance and repair costs.
Technological	When a newer version becomes available that performs the function better.
Ecological	A new product with a less harmful impact on the environment is available.
Psychological	Emotional value to favour a product over another product e.g., gift.
Absolute	
Qualitative	Break down or wear of products.
Functional	The functions of components are no longer used.
Technological	When an older version is no longer supported.
Logistical	When products or components are no longer available to procure.

There is a growing interest in repairing household appliances in the UK, which can help avoid qualitative obsolescence. Many households are realising the benefits of repair as it provides money-saving opportunities by reducing the need for replacement and associated costs of purchasing a new appliance and disposing an old one. According to a report by the UK charity Hubbub (2020), 75% of UK households would like to see more repair services for household appliances, and 82% of people surveyed said they would like to keep their appliances for longer. The report also found that 40% of households have already repaired a broken appliance in the past year. The UK government is also taking steps to encourage appliance repairs.

Maintenance activities can contribute to product life extension by avoiding both aesthetic and qualitative obsolescence. Maintenance activities include cleaning products and any other activities that work to prevent or minimise wear and tear caused by use, including descaling, running care cycles and emptying traps or filters. The distinction between repair and maintenance of appliances is not clear cut and often the two activities overlap (Laitala et al., 2021). For this study, repair is considered a response to a break in functional obsolescence (broken part, or appliance can no longer be used for desired function) whereas maintenance is defined as the regular cleaning and preventative actions taken to avoid product breakdown. However, there is a recognition that these definitions still contain overlapping activities, such as when appliances are cleaned to reverse both functional and aesthetic obsolescence (i.e., cleaning a hob to unclog gas burners) (Allcott and Mullainathan, 2010).

There are other elements that contribute to product life extension aside from repair and maintenance. Design plays a significant role since products can be designed for repairability, modularity, and physical and emotional durability (Haines-Gadd et al., 2018). All these design factors can contribute to consumer willingness to keep and use products for the entire duration of their functional lifespan. Creating societal, legislative, and commercial environments optimised for product longevity is also crucial.

1.1.5. Influencing Resource Efficient Behaviours: Consumer Education

Behaviour change has also been established as an effective strategy for ensuring energy efficiency, both from a cost and outcome perspective (Allcott and Mullainathan, 2010). With low consumer literacy on energy use, there is potential for substantial behaviour change through education. In some cases, consumer education has helped individuals reduce their energy consumption by 7.4% (Delmas, Fischlein and Asensio, 2013). Providing information to consumers and increasing energy literacy can support the adoption of new behaviours since it helps to decrease uncertainty for consumers (Casado, Hidalgo and García-Leiva, 2017). In the context of a cost-of-living crisis, it was anticipated that consumers would be motivated to change their behaviours to save money where they can.

Previous work on energy consumption education has tested what types of messages are effective, and what motivates consumers to save energy (Casado, Hidalgo and García-Leiva, 2017). This work finds that consumers respond to messages that suggest specific behaviours (i.e., use LED bulbs, turn off the lights) rather than more generalised information (you can save energy at home). They are also largely motivated by economic incentives such as saving money on energy, though environmental values can act as a motivator as well. However, cessation of

energy saving behaviour once economic incentives are no longer present suggests that economic incentives are stronger than environmental. Previously, messages have been tested for their effectiveness at changing consumer intention, however there is a need for testing their effect on actual behaviour (Casado, Hidalgo and García-Leiva, 2017).

1.2 Contributions

This study builds on previous work on resource efficiency behaviours of domestic appliance consumers but is novel primarily because of its timing. This study is being carried out in a post-covid environment, during which many UK households changed their appliance use behaviour because of new hybrid working and work-from-home routines. It is also being carried out during the cost-of-living crisis in the UK, which is characterised by higher costs associated with essential goods such as food and energy. We anticipate that these factors will influence household appliance use and household resource efficiency.

An additional contribution this study brings is the focus on repair and maintenance behaviours in UK households. Numerous studies have looked at behaviours associated with energy efficiency (including purchase habits and appliance use), but less emphasis has been put on observing consumer behaviours that extend product lifetimes. These behaviours help reduce the frequency at which new appliances need to be obtained, and thus decrease the environmental impacts associated with appliance manufacturing. Understanding what barriers and enablers consumers encounter when attempting to repair and maintain their appliances can help inform further research, appliance design, consumer education, and policy aimed at encouraging these behaviours.

1.3 Aims

This study has been carried out through a collaboration between the UKRI Circular Economy Hub (University of Exeter) and Association of Manufacturers of Domestic Appliances. This aim of this study is ***to demonstrate how changes in human behaviour can result from consumer education, and in turn help to reduce the costs of living by decreasing the use of energy and resources associated with consumption of domestic appliances.***

The objectives of this study are to:

1. ***Conduct field research on household behaviour*** to study energy efficiency and resource efficiency behaviours, in the context of how households interact with appliances in the use phase and what factors influence their behaviour.
2. ***Develop and administer behaviour change interventions*** in the form of consumer education messages to instruct and nudge household resource efficiency behaviours, and ***monitor changes in household behaviour*** and analyse associated barriers and drivers.

2.0 Methodology

2.1. Scope

2.1.1. Behaviours

This study examines two distinct types of human behaviour that lead to resource efficiency. The first type is a recurring behaviour that achieves resource efficiency when performed daily, whether intentionally or not and includes using eco-settings (e.g., using a dishwasher), making full use of available space (e.g., using a washing machine) and spending less time performing a task (e.g., when cooking using an oven), all of which are associated with using less energy. In addition, the recurring energy-efficiency behaviour concerns the use of assistive resources that are also consumed daily to facilitate the utility of appliances, such as water or detergents.

The second type is related to extending product life through maintenance and repair, thereby contributing to achieving a circular economy for appliances. Maintenance aims to prolong the operation of an appliance before it breaks and covers behaviours such as cleaning, clearing filters and descaling to lengthen the life of the appliance. While repair similarly aims to extend the product life, it is typically performed in instances where a broken component alters the function of an appliance and therefore requires fixing. This covers behaviours such as replacement of a broken lightbulb, torn seals or failed electrical elements. While maintenance is a behaviour that can be embedded part of a consumption routine (e.g., take place weekly, monthly or once a year), repair links to a product end-of-life (e.g., an event when the function of an appliance becomes altered significantly and lead to its disposal) meaning it occurs sporadically and results in significant improvements to the appliance performance.

2.1.2. Household Electrical Appliances

Appliances were selected based on their necessity to complete essential household activities, such as cooking, laundering, dishwashing, and refrigerating (see Table 2 for relationships between activities and appliances). This final list of core appliances was decided upon review of appliances owned and used by the participating households.

Table 2. Essential household activities and associated appliances

Essential Household Activities	Associated Appliances
Cooking	Hob; oven; microwave; air fryer; slow cooker; dishwasher
Laundering	Washing machine; tumble dryer; combination washer/dryer
Boiling Water	Electric kettle; hob
Refrigerating	Fridge/freezer (defined based on age and model – old, new, smart)
Cleaning	All appliances, Assistive elements (associated with the activity of maintaining, frequency and approaches)
Repairing	All appliances, Assistive elements (associated with the activity of maintaining, frequency and approaches)

2.2. Participants

After receiving 54 responses in the Southwark council newsletter, a sample of 7 eligible households were selected and invited to participate in the study, referred to as H1 – H7 throughout this report. The sample consisted of the following household formats: one-person, households (N=2), couples with no children households (N=2), couples with one or more dependent children (N=2), and lone parent with a dependent child (N=1). Other notable attributes of the households include:

1. All adults (18 years and older) are employed full-time.
2. Five households' current working arrangement is hybrid (sometimes at home, sometimes from workplace). Household 5 (H5) works from home full-time. Household 3 (H3) has one occupant working hybrid and one from home full-time.
3. Households' annual income (before tax) ranged from £40,000/year to over £140,000/year. Four households reported an income of £100,000/year or more.
4. Adults from four households have a university education at a master's degree level or higher. Adults from the remaining three households have attained undergraduate degrees.

The study also took into consideration the households' degree of eco-consciousness. There is a definitive mix in responses to enquiries regarding consideration for environmental impacts when purchasing and using household appliances, on a 5-point scale ranging from 'never' to 'always.' Only 2 households 'always' consider impacts at point of purchase, and only 1 household 'always' considers impacts when using appliances.

2.3. Research Design

This study used multiple methods to collect data on household resource efficiency behaviours. It spans across three phases, making up the 3-month multi-stage field research (January to March 2023). The collected data was gathered primarily from qualitative interviews, surveys, and behaviours chain maps developed from observations, accompanied by quantitative descriptive data from survey responses and outputs from mixed method approach employed to record appliance usage.

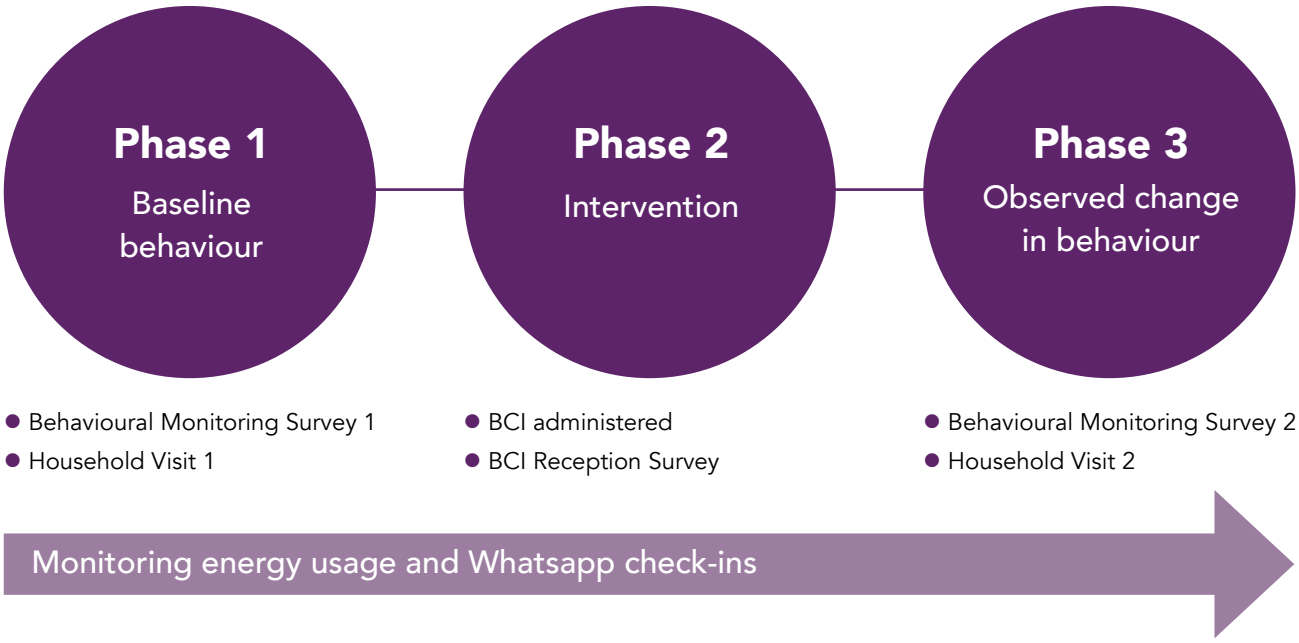
Phase 1 established baseline routine behaviours and associated costs for all households in their household current set-up (i.e., participants will showcase using their appliances as 'normal'). Data was collected through Behavioural Monitoring Survey 1, designed using the COM-B framework and delivered prior to Household Visit 1. During the household visit researchers observed laundering, cooking, and water boiling routines and mapped them out in the form of behaviour chains (Muranko et al., 2020). Participants used the 'think aloud' method to share insight on their understanding and reasoning as they interacted with their appliances (Pozo Arcos et al., 2021).

Afterwards they took part in a semi-structured interviews to share further insights. Energy meters were also installed on eligible appliances for the purpose of measuring the effects of changes in behaviour.

Phase 2 involved designing a behaviour change intervention, in the form of consumer education messages, informed by literature review and the preliminary results of the study (i.e., Phase 1) and distribution of the behaviour change intervention to the households via the WhatsApp messaging platform. Participant then filled out the Behaviour Change Intervention Reception Survey to share their impressions of the messages and report on their intentions to perform each of the behaviours targeted in the consumer education.

Phase 3 repeated the data collection methods used in Phase 1 to evaluate the effects of the consumer education messages on behaviour and identify the difference in results. The focus of this phase was to observe changes in routines, note new behaviours, and understand participant barriers and enablers to performing resource saving behaviours. The Behaviour Monitoring Survey and Household Visit 2 were carried out 4 weeks after the behaviour change intervention was administered in Phase 2.

Figure 2. Research design showing three phases of the study.

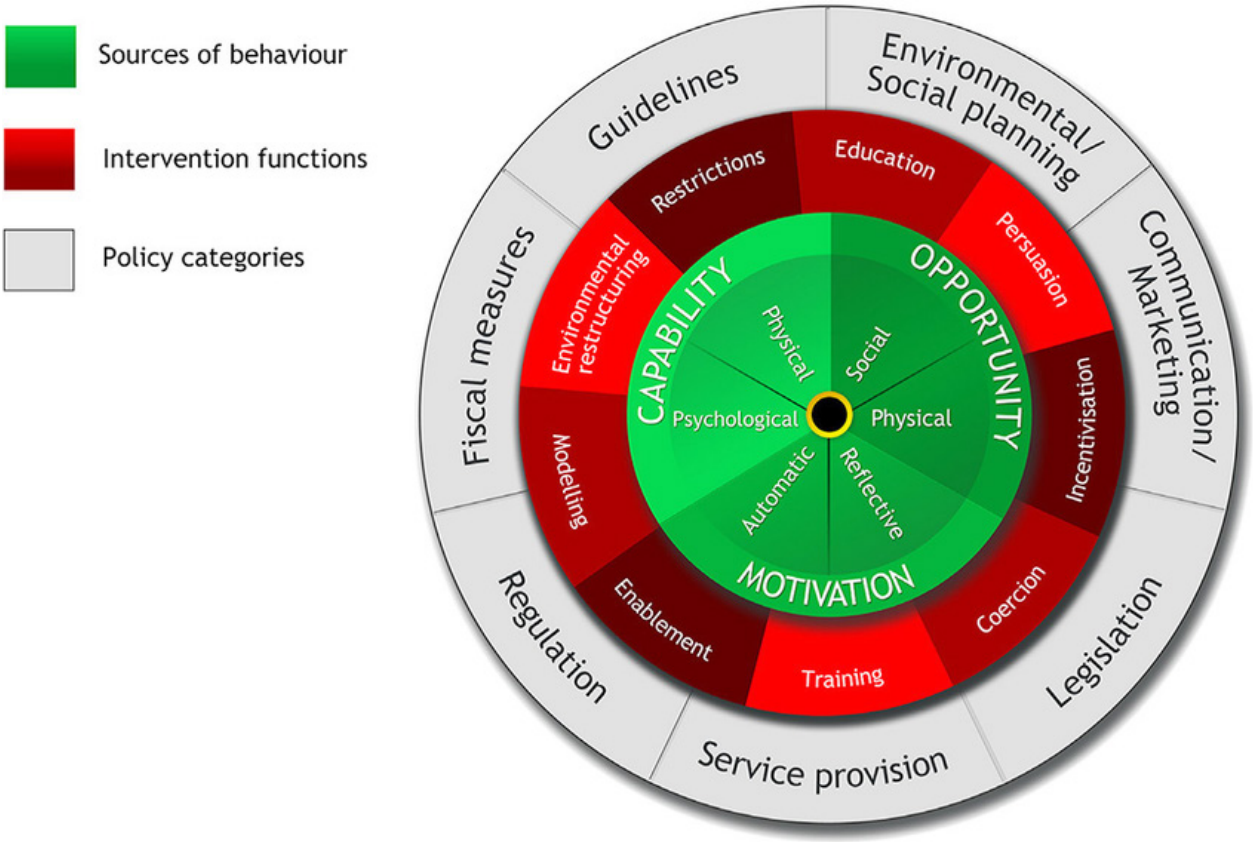


2.4 Behavioural Models

The main theory underpinning this study is the COM-B model (see Fig. 3). COM-B outlines three elements needed for a behaviour to occur: capability, opportunity, and motivation (West and Michie, 2020). It is commonly used to help identify what needs to change for an intervention to be effective. Thus, the Behavioural Monitoring Surveys recognise how these factors initiate interactions of the participants with their household appliances. The general hypothesis is that the participants will need capability and opportunity to engage in their behaviours, as well as targeted motivation to enact that behaviour. By understanding these three elements of behaviour, researchers could identify the types of barriers and enablers participants encounter as they perform their various routines.

Further, the survey was also informed by Triandis' (1977) integrated model of interpersonal behaviour, with a particular focus on the factor of habit. This model differentiates itself from other behaviour models, by acknowledging the importance of "habits as a mediated factor of behavioural change". Given that the targeted behaviours of this study are habitual, it was important that this factor was considered when attempting to understand participant behaviours.

Figure 3: Behaviour Change Wheel (Michie, Atkins and West, 2014)



2.5. Analysis

Comparative analysis of behaviours, and of impact on energy use, resource use and costs were carried out. The resulting themes are derived in the results section.

2.5.1 Qualitative Data

Coding of the extensive data points was undertaken in NVivo, a collaborative qualitative analysis software. Thematic analysis was employed to form themes. The relevant qualitative data was attained from: 1) Survey responses (Participant Screening Survey, Behavioural Monitoring Survey 1 and 2, Behaviour Change Intervention Reception Survey). 2) WhatsApp messages. 3) Household observation materials (audio recordings, behaviour chain maps, interview and observation notes).

2.5.2 Quantitative Data

Descriptive statistics informed observed changes throughout the study derived from survey responses. Quantitative data was also derived from the energy and resource usage, and associated costs, measured on installed energy monitoring devices data and completed appliance use sheets, from the entire duration of the study.

5-point Likert scales were used to enable participants to report the level of agreement or likelihood of performing a behaviour in question, scoring between 1 to 5 (where 1 – corresponded to extremely disagree/extremely unlikely; 2 - somewhat disagree/somewhat likely, 3 - neither agree nor disagree/neither unlikely nor likely; 4 – somewhat agree/ somewhat likely, 5 – extremely agree/ extremely likely). Variables that are accounted for include cooking, laundering, and boiling water (as part of cooking or beverage making) using the appliances they own. Furthermore, Phase 3 survey also included questions that involve participants reporting on frequency where 5-point never–always scales were used.

3.0 Results

This section presents an analysis of quantitative and qualitative data gathered on the energy efficiency and product-life extension behaviours of the participants both before and after consumer education, demonstrating the effect of the intervention on participants intentions and their actual behaviour. This data was gathered from participant responses to the study's surveys and observations of their households.

3.1 Change in Energy-efficient Behaviours

3.1.1 Capability

At the start of the study, the participants stated they did not have any physical restrictions when using their own appliances. Concerning psychological capability (see Appendix 1), the initial assessment of the knowledge of how to increase energy efficiency when using appliances revealed a general reluctancy to agree (x= 2.6, SD=1.1). Also, the households had an overall mixed view on whether they knew how to improve their appliances efficiency with answers falling on both sides of the scale, positive and negative. Examples of that are participants knowledge of dishwasher's efficiency (x=3.3, SD=1), with the lowest knowledge of efficiency being reported for their microwave (x=1.6, SD=0.9).

"I'm not aware of anything I could do differently or could change to improve energy-efficiency of my appliances"

Post-intervention, the results show a notable increase in general knowledge to improve energy efficiency with a stronger degree of agreement across households and appliances (x=3.9, SD=0.8). Except for one appliance (slow cooker), on average all households agreed to knowing how to improve efficiency across all appliances. For example, the original negative response to the microwave (x=1.6, SD=0.9) improved significantly (x=4.2, SD=0.5). This means that on average, households went from claiming that they 'strongly disagree' to 'somewhat agree' to knowing how to improve the energy efficiency of their appliances after receiving the consumer education in Phase 2. The lower overall standard deviation (from SD=1.1 to SD=0.8) also indicates that the responses were more closely clustered around the average answer of 'somewhat agree' after receiving the consumer education messages.

The study identified several explanations for why the households only 'somewhat agree' to knowing how to improve energy efficiency even after the intervention. Primarily, it appears that participants guess what the right amount of water is (and fill up the kettles without taking a precise measure) for them to be able to save the energy when boiling. Additionally, some participants simply lack the required knowledge on how to boost energy-efficiency of their appliances. This is exemplified by H7, who reported: "I'm not aware of anything I could do differently or could change," to improve energy-efficiency of their appliances.

There is a common confusion and lack of confidence in appliance settings, which causes difficulties for consumer appliance-related decision-making. H2 commented: "I can use my washing machine well but have always wondered whether a 3-hour eco wash really is more environmentally friendly than a 1-hour speed wash, which is why I didn't put 'strongly agree", which is an example of this confusion. H2 also stated that the settings information physically wears off, making it difficult to use any settings other than the one they figured out: "I spent a very long time looking for the manual online, figured out the main setting to cook with and don't use it on any other setting, because I am not sure what they are!" This confusion highlights the need for clear, physically durable and accurate labelling of appliance settings.

"I can use my washing machine well but have always wondered whether a 3-hour eco wash really is more environmentally friendly than a 1-hour speed wash"

3.1.2 Opportunity

The households generally disagreed that they feel they have an opportunity or option to save energy when using their current appliances (x=2.7, SD=1.1). The appliance most acknowledged as having potential to have improved energy savings are washing machine (x=4 SD=1.4), whilst toasters are widely perceived not to have many energy-saving options (x=1.5, SD=0.5). Upon receiving the consumer education messages, participants' responses in relation to them perceiving that they have an option to save energy when using their appliances improved on average for most appliance types they own, however, still hover in the 'neither agree nor disagree' space with a mix of responses falling on both sides of scales (x=3.15, SD=1). Perceptions of the energy efficiency of the hob (before intervention: x=1.9, SD=0.4; after intervention x=3.1, SD=1.2) and fridge (before: x=2, SD=0.8; after x=3.3, SD=0.9) improved with a mix of positive and neutral responses to participants perceiving they have options for energy saving following the education.

Technology, Norms, and the Environment

When considering the opportunity to perform energy efficient behaviours, there is a reliance on the design of the technology itself to directly inform users of best practice. If eco-settings are not present, or 'obvious' (as stated by H4), there is a perceived lack of opportunity to perform behaviours that are more energy efficient. There is a desire to perform more eco-behaviours, but technology can be limiting, and as reported by participants - 'frustrating'.

On the other hand, the case of H7 exhibits the benefits of appliances with smart capabilities. For example, their washing machine automatically weighs loads to determine the most efficient wash and spin cycle for each individual wash. Whereas their kettle, as well as H5, has the capacity to be boil water to different temperatures. The study showed that these features are key enablers of energy-efficient practice.

The environmental context also factors into how some households choose to behave. For example, H3 confirmed that they "run [the dishwasher] at night-time to get night rates." Other environmental/contextual factors that determine appliance use behaviour includes consciousness of neighbours (i.e., H2 notes not running spin cycles at inconsiderate hours), and weather conditions (i.e., H5 affirmed that wet weather means greater likelihood of using tumble dryer, so tries "not to use the dryer much in warm weather").

"There is a desire to perform more eco-behaviours, but technology is perceived as limiting and frustrating."

Participants shared that many of their habitual appliance use behaviours are as a result of socialisation. For example, H1 and H2 indicate that their behaviours have been influenced by family. H1 became accustomed to hand-washing dishes after spending a period of time living with their grandmother, whilst H2 shared that they "keep food in the same parts of my fridge that my parents did when I was younger." Further, H6 acknowledged a much greater uptake of dishwasher, washing machine, and tumble dryer use since having a child. H6 also expressed a division of labour across some appliances. They stated that, "my wife uses the drier," therefore does not feel a need to know how to operate it.

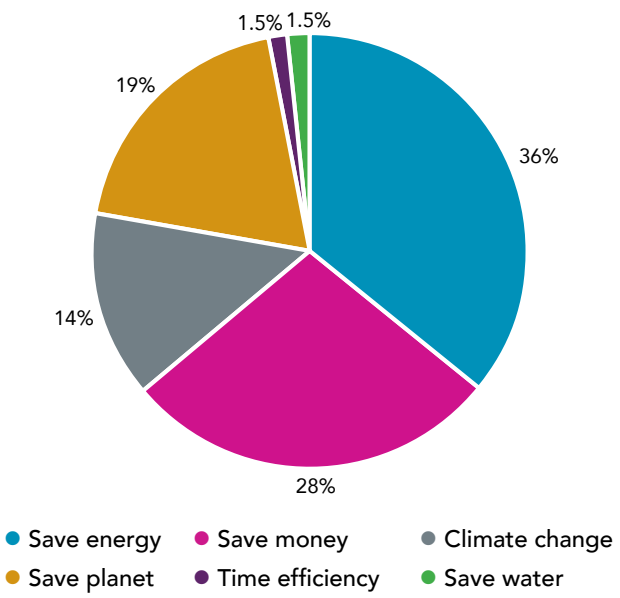
This socialisation impact is broadly exhibited across all households because of new working arrangements post-COVID-19 pandemic, which have seen participants physically much more present at home, thus using appliances more. These changing work circumstances, alongside the present cost-of-living crisis, have also impacted appliance use. H2 recognised that, "I am more economical with how I use my oven / hob – e.g., trying to limit use, or make more efficient use of them when they're on." This sentiment was echoed by H5 who noted numerous changes to routine: "I am more likely to batch cook to use oven and hob less, and therefore use the freezer more. I am also more likely to make sure the tumble dryer is full to maximum before I use it. And I more likely use auto setting on washing machine where the cycle length is based on the weight of the washing. I also use exactly the right amount of water in the kettle and use lower temperature setting."

Interestingly, despite these examples, across all households, 2/3 of the responses to the statement that 'how they use appliances now differs from how they used them before the 'cost of living crisis'/Covid-19' were 'strongly disagree' contradicting the routine changes reported by participants, as in examples above.

3.1.3 Motivation

Of the responses given by participants for the appliances studied, 36% reported that saving energy was their main motivating factor for choosing energy saving options when using their appliances. Saving money (28%) and saving the planet (19%) were also major motivators, along with mitigating climate change (14%), and both increasing time-efficiency and saving water (1.5%) (Fig. 4). The motivations were consistent across appliances. It is important to note that all the participants used the term 'saving energy' but there was no uniform definition of it. It is unclear if their motivation was cost or environmental benefits, as it could be both.

Figure 4. Pre-behaviour change intervention motivations to choose energy saving options on appliances



There are three other notable motivating factors reported by participants. The perception of the task's ease and convenience play key roles in whether participants choose to engage in energy-efficient behaviour. This was evident in comments about oven use, with both H2 and H5 stating that they prefer to use the hob during the week for convenience. Another factor is the willingness to forgo other expenses and waste to save energy. H2 said that they prioritised reducing food waste

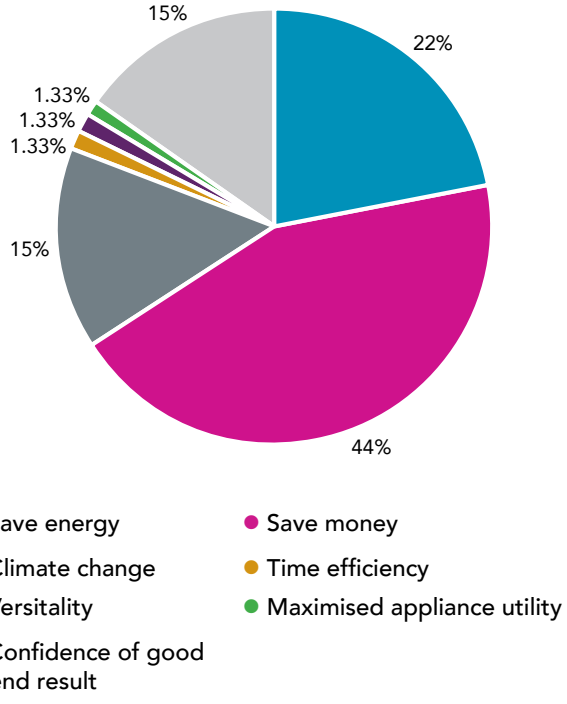
over saving energy, while H7 admitted that they were not motivated to perform energy-efficient behaviours on appliances due to the minimal cost savings compared to their high heating bill. Lastly, saving time was a motivator as well and occasionally aligned with energy-saving behaviours (boiling the kettle to a lower temperature). Though in the case of eco-settings (longer wash cycles) saving time acted as a barrier to energy-saving.

Four weeks post-intervention, new motivational factors to use energy saving options appeared. As per Fig. 5, participants are now being motivated by versatility (i.e., microwave) (1%), the ability to maximise appliance utility (e.g., washing machine used to full capacity of space) (1%) and 'confidence of good end result (i.e., optimal functionality) (15%). Participants remained motivated by environmental issues (i.e., climate change) (15%), yet a greater emphasis was on saving money (44%) and energy (22%). This suggests the intervention had been powerful in targeting these leading factors of motivation.

"I prioritise reducing food waste over saving energy, so I rather my fridge runs on the cooler setting."

"I am not that motivated to perform energy-efficient behaviours on appliances because the cost savings are minimal compared to my high heating bill."

Figure 5. Post- behaviour change intervention motivations to choose energy saving options on appliances



3.2. Change in Product-life Extension Behaviours

3.2.1 Capability

A notable physical barrier to perform product life extension behaviours is participants having appliances that are integrated (i.e., not free-standing). These lead to perceived, and actual, lack of access to perform maintenance activities. For example, it is not practical for H4 or H5 to access the back of their integrated fridges to clean coils.

The extent to which the participants had the psychological capability to carry out maintenance activities, to make appliances last longer or prevent them from damage or breaking, was generally low (see Appendix 1). The average response across all appliances was overall tentative 'neither agree nor disagree' with answers falling on both sides of the scale (x=2.8, SD=1.2). Upon receiving the consumer education messages on maintenance activities, this response improved notably with more participants responding positively to the statement (x=3.5, SD=1.2). Following the intervention, all bar one (the airfryer, which is only applicable for 3 households), attained an average response of now 'strongly/somewhat agree' to knowing how to carry out maintenance activities. The hob (before intervention: x=2.3, SD= 1.4; after intervention: x=4.3, SD=1.1) and the oven (before: x=2.3, SD= 0.9; after x=3.9, SD=1.3) received the most notable improvement in knowledge across the households.

Regarding repair, on average (as per Appendix 1), all participants expressed they have limited knowledge on how to repair their appliances if they break (x=1.8, SD=1), declaring that they either 'strongly' or 'somewhat' disagree with them having capability to repair. There were minor changes post-intervention however the average response remained on the negative side of the scale (x=2.1, SD=0.9), which is consistent with the fact that the consumer education administered in Phase 2 of the study, predominantly targeted specific maintenance actions. Nonetheless it is possible that some of these actions can be interpreted as repair (e.g., component replacement, such as changing a broken fridge seal). Upon the screening of participants appliances, the majority of which were in a good working order, the consumer education was skewed towards maintenance behaviours, as change in maintenance behaviour was more likely to be observed in the timespan between Phase 2 and Phase 3 of the study – 4 weeks - as opposed to the repair.

3.2.2 Opportunity

Prior to the consumer education messages, participants disagreed (x=2.4, SD=1.4) that there was an opportunity or option for them to carry out maintenance activities on their current appliances overall to make them last longer or prevent them from damage or breaking. Encouragingly, post-intervention, these responses improved notably across all appliances (x=3.8, SD=1.1). Prior to the intervention, only one appliance (washing machine) managed to receive even a neutral response, whilst the others were all, on average, disagreed to. Whereas, post-intervention, answers across seven of the twelve appliances improved to average at 'somewhat agree' (i.e., microwave, washing machine, tumble dryer, kettle, fridge, freezer, and dishwasher), and only 2 remained disagreed to (i.e., air fryer and slow cooker).

The overall response to opportunity to repair was generally neutral with answer falling widely on both sides of the scale (x=2.6, SD=1.5). There was no notable change in response following the consumer education messages (x=2.4, SD=1.2). There is no consistency across appliances that were, on average, agreed to have the opportunity to repair pre-intervention (i.e., washing machine, fridge, and freezer) and post-intervention (i.e., air fryer and toaster), as seen in Appendix 1. It is assumed that the messaging negatively influenced the responses, especially for the washing machine, fridge, and freezer, as learning more about their operations and technical features could have led to a decreased perception towards there being an opportunity to repair.

Technology, Norms, and the Environment

The participants commented on how external factors can limit their ability to perform product life extension behaviours, such as maintenance or repair. The study found that maintenance behaviours are usually triggered by visual or auditory cues and are typically (in six out of seven households) not regularly scheduled, except for H6 who employs a cleaner who carries out activities to deep clean of appliances monthly. Maintenance behaviour is commonly associated with hygiene, rather than preventative care, i.e., activities households can undertake to prolong the operation of an appliance before its function is altered. Technology, however, can help to reduce the reliance on physical indicators to determine when maintenance behaviours should take place. For example, H7 has a smart home set-up, with virtual home assistant technology interconnected with their IOT appliances, including a smart washing machine, dishwasher, and kettle. These smart appliances use technology to remind the household occupants to perform cleaning and other maintenance activities at time intervals. The reminders are shown for example, on the appliance interface screen as well as within the corresponding smartphone applications. One example is H7's dishwasher, which displays a message on its interface regularly reminding the consumer to 'add new salt' when it has recorded a need for replenishment.

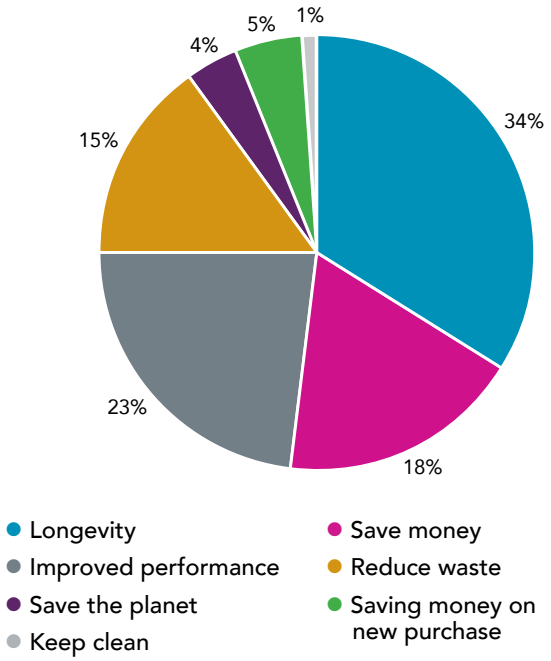
Social norms also play a role in determining the uptake of repair behaviours. Each household indicates different extents to which they would be willing to repair, depending on their awareness of the faulty and the repair process itself, and their prior experience or interest in undertaking DIY projects. For example, H7 shared that, "I'm not aware of anything I could do," whilst H4 accepts that they, "don't have the knowledge on how to replace parts if they are faulty. I can only do basic maintenance like cleaning or descaling." Meanwhile H2 shared that their repair limit is anything, "beyond trying to replace the fuse," because those tasks are, "either too big or too dangerous for me to try," and H5 acknowledges that "amateur fixing of electrical items is discouraged." This perceived lack of opportunity is further exacerbated by participants' discernments of the intentions of manufacturers. H5 states that, "manufacturers don't make it easy to [repair] and usually state all repairs have to be done by a qualified electrician." Thus, there is no common extent to which individuals feel they have the opportunity to perform product life extension behaviours.

3.2.3 Motivation

The main motivating factors driving participants to carry out maintenance behaviours on the appliances include and increased longevity of reported by one third of participants, improved performance reported by one quarter and saving money reported by one fifth. Other motivating factors included reduction of waste, saving money specifically

on new purchases and saving the planet reported by less than 15% of participants (Fig. 6). Interestingly, maintenance for the simple purpose of keeping the appliance clean was only recorded for one appliance, an electric kettle, for one participant.

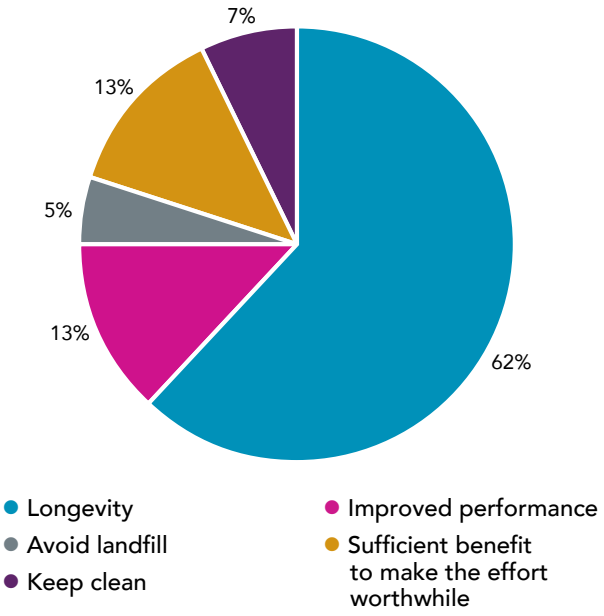
Figure 6. Pre-behaviour change intervention motivations to carry out maintenance activities on appliances



Following the education intervention, the intention to perform maintenance behaviours for the purpose of prolonging appliances life almost doubled to two thirds of participants listing it as a key motivational factor (Fig. 7). H2 elaborated on this motivator, acknowledging that they require the use of their appliances, notably the washing machine, kettle, and fridge, very frequently and "wouldn't want any downtime."

Any explicit reference to environmental benefits (i.e., saving the planet) were completely removed from responses overall post-intervention. Interestingly, a new motivational factor was recognised as maintenance is perceived to bring 'sufficient benefit to make the effort worthwhile' (recorded at 13% of responses). This follows participants' consideration of the actual amount of effort required to complete maintenance activities, relative to allowing their existing appliances to cease functioning/ break and simply purchasing a new appliance. This is echoed in the fact that any reference to 'saving money' is also eliminated as a reason to perform maintenance behaviours. Improved performance remains a motivator of maintenance behaviour at 13% of participants responses, whilst 'reducing waste' is replaced with more specific intention to avoid landfill (at 5%). Performing maintenance for the purpose of keeping the appliance generally clean increased to at 7% of participants responses.

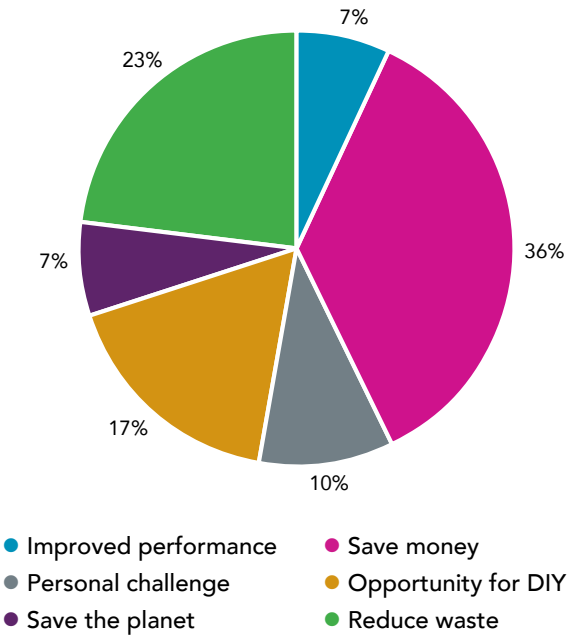
Figure 7. Post-behaviour change intervention motivations to carry out maintenance activities on appliances



As in Fig. 8, the main motivation to perform repair behaviour on appliances was to save money, recorded at 36% of participants responses, and reducing waste, (23%). Other motivating factors reported by participants included an opportunity to DIY (17%), to take on a personal challenge (10%), improve appliance performance and saving the planet, both recorded at 7%. The opportunity to DIY and taking on a personal challenge were uniquely reported for repair behaviours only.

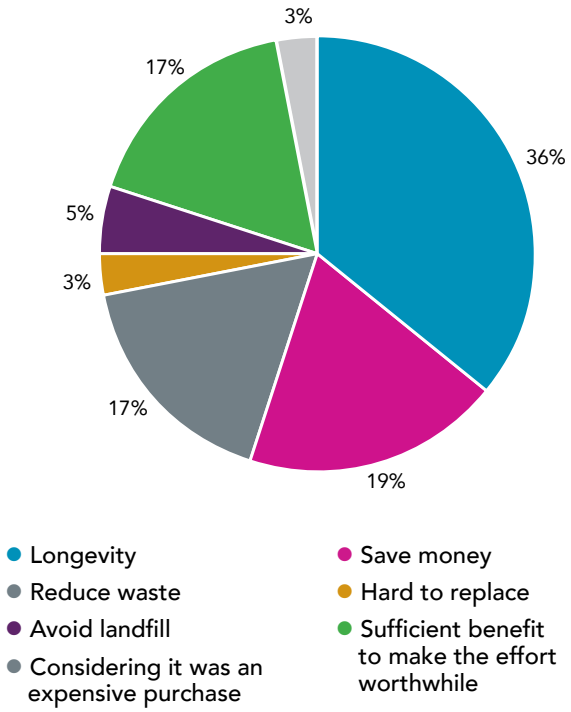
H2 expresses that they "hate paying for something [they] can do [them]self." However, this sentiment is challenged by responses of other participants in the study. H7 is not convinced that repair is the most cost-effective decision, which is because they perceive that instead of attempting DIY, they would employ professional help, recognising that "the cost of the new appliances would be lower than the cost of engaging an engineer to troubleshoot and repair."

Figure 8. Pre-behaviour change intervention motivations to carry out repair activities on appliances



Following the consumer education, increased appliance longevity became the leading reason for repair, reported by 36% of participants (Fig. 9). This result is an important demonstrator of how consumer education might be effective in influencing household behaviour, as prior to the intervention, and increased appliance longevity was not considered by any study participants as a factor motivating their decisions to perform repair behaviours on their appliances. Although saving money remains the second motivator reported one fifth of the participants, it is less considered as a main factor motivating participants repair behaviour (with number of participants specifying it as a motivating factor almost halving post-intervention, nonetheless still being reported by one fifth of the sample). Reducing waste (17%) and avoiding landfill (5%) also remain important motivators of repair. Interestingly, following the intervention, three new motivating factors were reported, including there being a perceived 'sufficient benefit to make the effort worthwhile' reported by 17% of the sample a result that is similar to maintenance reported in the previous section. For example, H2 commented about their microwave, that they "wouldn't mind an upgrade if it's an easy fix." Other newly reported motivating factors included the purchase of a new appliance being an expensive activity and there being a difficulty to facilitate appliance replace (such as due to features of a household layout).

Figure 9. Post-behaviour change intervention motivations to carry out repair activities on appliances



3.3 Past behaviour, Intention and Actual Behaviour

3.3.1 Behavioural Intentions Pre- and Post-Intervention

Table 3 presents the behavioural intention of participants to perform energy efficiency and product life extension behaviours both, pre-intervention, measured at the beginning of the study, and post-intervention, measured 4 weeks after the educational messaging was administered. As summarised in Table 3, there are no notable changes in intention across the three behaviour groups. Despite minor changes in responses, all averages remain similar across. For example, the mean (from x=4.17 to x=4.02) of responses for the intention to perform maintenance behaviours remained similar, indicating that participants were inclined to perform these behaviours in the future, whether informed of their benefits and procedures, or not. However, there has been a decrease overall in standard deviation (SD) of responses, which indicates that the reported post-intervention responses were more closely clustered to the positive mean average, highlighting a higher consistency in answers. These results are further explored in the sub-sections below. explored in the sub-sections below.

Table 3. Behavioural Intentions pre and post behaviour change intervention (consumer education messages)

Behaviour	Behavioural Intention before Intervention	Behavioural Intention post Intervention
Energy efficiency	Average response: Neither likely nor unlikely Mean= 3.9 SD= 0.87	Average response: Neither likely nor unlikely Mean= 3.9 SD=0.93 SD= 0.87
Maintenance	Average response: Somewhat likely Mean= 4.17 SD= 1.07	Average response: Somewhat likely Mean= 4.02 SD= 0.84
Repair	Average response: Neither likely nor unlikely Mean= 3.5 SD=1.34	Average response: Neither likely nor unlikely Mean= 3.04 SD= 1.33

3.3.1.1 Behavioural Intention to Perform Energy Efficiency Behaviours: Pre- and Post-Intervention

Before being exposed to the intervention (consumer education), on average, the households were hesitant to make any commitment to always choose an option to save energy when using their appliances in the future at the start of the study (x=3.9, SD=0.9) (see Table 3), commonly electing to state that they are 'neither likely nor unlikely'. There were five appliances (oven, hob, washing machine, tumble dryer, and kettle) that averaged a positive 'somewhat likely' response. A reason for the general hesitancy to strongly commit to choosing energy saving options across appliances can be the fact that several households are under the impression that they are already using their appliances efficiently, as demonstrated in the statements of few participants: "I think I already use these appliances efficiently or there are limited options to make my use more efficient" - H1;"Microwave and toaster I feel are already used optimally." - H2; "I think I am already trying my best to save energy on the appliances I have." - H4

Following the consumer education, the average response remained similar as pre-intervention for almost all appliance), except for dishwasher. There has been a notable increase in an intention to choose an energy saving option during the dishwasher use rising from neutral (x=3.5SD=1.7) to positive (x=4.4, SD=0.9).

3.3.1.2 Behavioural Intention to Perform Product Life Extension Behaviours: Pre- and Post Intervention

Interestingly, despite results gathered before intervention (consumer education) suggesting participants had a lack of knowledge and perceived there was a lack of opportunity to carry out maintenance on appliances to make them last longer or prevent them from damage or breaking, on average all households reported there was a desire to maintain their appliances in the future (x=4.2, SD=1.1). Participants shared examples of maintenance behaviours they already undertake on their appliances. H2 spoke of performing maintenance upon there being visible indications of dirt, by pointing out that they "descale the kettle and remove crumbs from the toaster" when there was a visible indicator that these required cleaning. H3 instead performs regular cleaning of washing machine, kettle, and toaster, even without there being any visible cues indicating there is a need to do so. H4 defrosts their fridge / freezer "every now and then." H5 and H7 also shared they are performing some maintenance behaviours that are instructed by their appliances. For example, H5 runs a "'care' programme on dryer when prompted," and H7 responds to their washing machine/tumble dryer prompt to "clean drum."

Following the consumer education, the responses in the context of intentions to maintain appliances did not see any notable change). Households claim to be the most likely to maintain some of their appliances more than others. They are most likely to maintain their hob, washing machine, tumble dryer, and dishwasher, whilst remain indifferent/neutral about maintenance for their slow cookers and airfryers. This indifference can be linked to the fact that some appliances are not used as frequently and are not considered primary facilitators of their daily routines.

For repair, with there being an overall negative result indicating participants perceive they lack knowledge and opportunity, there was a neutral and slightly negative willingness to repair appliances with mixed answers overall (large SD indicated responses falling on both, positive and negative side of the scale x=3.5, SD=1.34). Post-intervention the intention to perform repair behaviour on appliances remained similarly neutral/negative and mixed (x=3, SD=1.3). However, a previously stated, it is worth noting, that the intervention (consumer education) centred on promoting maintenance behaviours, deemed observable during the course of the study. Therefore, any change in behaviour intention to repair would not be attributed to the intervention administered in the study, but to other factors.

3.3.2 Measurable Changes in Behaviours Relative to Intentions

3.3.2.1 Specific Behavioural Intentions and Actual Behaviours following Educational Intervention: Consumer Education

Appendix 2 provides an overview of the 50 resource efficiency and product life extension behaviours communicated via the consumer education messages and the corresponding participants intentions to perform, as well as the actual behaviours performed post-intervention following. Immediately after being exposed to the consumer education messages, there was an overall strong positive intention among all participants to perform the 50 recommended behaviours. ***29 of the behaviours were reported by the participants as 'somewhat or extremely likely' to be performed by them.*** Only four behaviours received an overall negative response of being unlikely to be performed, which predominantly related to optimising energy efficiency of the fridge and cleaning fridge coils. The lack of intention to perform these specific behaviours can be linked to participants perceiving or actually having a physical barrier, such as the lack of access to the back of an appliance (e.g., due to being too heavy to move or integrated in fixed position). Another relevant factor is that the fridge is not perceived by participants as an appliance that is used actively (i.e., the interactions between the consumer and the fridge are simple and do not involve recurring decision-making operational programme setting, when compared with their interactions with other appliances). As explained by H2, "I don't consider the fridge as something I use... You barely see the fridge, in a way - I consider it part of the kitchen in the same way the counters are."

Table 4. Performance of behaviours by household

Household	Total Behaviours performed	No. of new behaviours	Affirmed behaviours
H1	11	3	8
H2	16	3	13
H3	25	2	23
H4	28	3	25
H5	27	9	28
H6	40	5	35
H7	23	2	21

Of the identified 10 most performed behaviours post-intervention, 2 were new to the participants, namely 'considering the size of laundry load when using washing machine' and 'ensuring to avoid opening the freezer door too frequently or for too long'. The other 8 behaviours were affirmed and continued by participants following reception of the consumer education messages. The actual performance of these behaviours corresponds with the strong positive intentions to perform them reported at the point of reception of the consumer education messages.

Table 5. Top 10 behaviours performed post-intervention

Appliance	Behaviour	Type of behaviour	Intention (mean) 1-5 rank likelihood	Action (mean) 1-5 rank likelihood 1-10 times performed	Type of Action	Households performing as NEW
Hob	Based on this information, how likely are you to clean your hob regularly in the future?	Maintenance	4.714	7.143	Affirmed	
Microwave	Based on this information, how likely are you to avoid running the microwave empty in the future?	Energy Efficiency	5	5	Affirmed	
Hob	How likely are you to cook on the ring closest in size to the bottom of your pan in the future?	Energy Efficiency	4.429	4.857	Affirmed	
Dishwasher	Based on this information, how likely are you to run a full dishwasher in the future?	Energy Efficiency	5	4.8	Affirmed	
Microwave	Based on this information, how likely are you to cover your food when cooking using your microwave in the future?	Energy Efficiency	5	4.8	Affirmed	
Washing machine	How likely are you to consider the size of laundry load when using your washing machine in the future?	Energy Efficiency	4.429	4.429	New	H1
Hob	Based also on the information above, how likely are you to use pans that match the size of your meal in the future?	Energy Efficiency	4.857	4.429	Affirmed	
Washing machine	How likely are you to load your washing machine at an optimal full load in the future?	Energy Efficiency	4.286	4.429	Affirmed	
Microwave	Based on this information, how likely are you to use the eco-setting in the future?	Energy Efficiency	4.667	4.2	Affirmed	
Freezer	How likely are you to ensure you avoid opening the freezer door too frequently or for too long in the future?	Energy Efficiency	4.333	4.143	New	H5

Only 3 actions were not performed at all by any household, namely replacing fridge seals, defrosting your freezer, and using the auto-defrost function. These actions were not taken because no household identified any seals in need of repair, and no apparent need to defrost their freezers in the four weeks since receiving the consumer education messages.

The interviews showed that 36% of the performed behaviours were new, suggesting that consumer education messages were influential of the behaviour change (see Table 6)**.**

38% of all recommended energy efficiency behaviours, and 25% of all recommended maintenance behaviours, were newly taken up post-intervention across varying households and appliances. The oven, washing machine and dishwasher had the greatest uptake of 4, 3, and 3 new behaviours respectively. Notably, 7 of the newly adopted behaviours were performed despite receiving 'intention to perform' reports that claimed participants were on average either neutral or negative about their likelihood to perform the behaviour.

Table 6. New behaviours performed post-intervention

Appliance	Behaviour	Type of behaviour	Intention (mean) 1-5 rank likelihood	Action (mean) 1-5 rank likelihood 1-10 times performed	NO. of times performed across households	Households performing as NEW
Dishwasher	Based on this information, how likely are you to load your dryer drum 3/4 full in the future?	Energy Efficiency	4.4	3.8		H5
	Based on this information, how likely are you to clean the dishwasher filter once a month in the future?	Maintenance	3.167	0.429	0-2	H4
	Based also on the information above, how likely are you to clean the dishwasher interior once a month in the future?	Maintenance	3.333	0.714	0-4	H4 H5
Freezer	How likely are you to ensure you avoid opening the freezer door too frequently or for too long in the future?	Energy Efficiency	4.333	4.143		H5
	How likely are you to consider keeping your freezer full in the future?	Energy Efficiency	4.667	4		H2 H7
Fridge	How likely are you to inspect your fridge door seals in the future for cracks or splits?	Maintenance	4.286	0.429	0-1	H3 H5 H7
	How likely are you to keep your fridge full in the future?	Energy Efficiency	2.857	3.286		H2

Hob	Based also on the information above, how likely are you to keep the lid on pans when cooking on the hob in the future?	Energy Efficiency	4	3		H1 H6
	Based on this information, how likely are you to use your microwave instead of the oven in the future?	Energy Efficiency	4	3.4		H6
Oven	How likely are you to turn the oven temperature to zero towards the end of cooking time to use some 'free' heat in the future?	Energy Efficiency	3.333	2.143		H5 H6
	How likely are you to avoid preheating in the future?	Energy Efficiency	3.333	3.143		H3
	How likely are you to cook several dishes at the same time in your oven in the future?	Energy Efficiency	3.5	2.143		H5 H6
	How likely are you to remove unnecessary accessories from your oven in the future?	Energy Efficiency	4.833	3.714		H4 H5
Tumble Dryer	Based on this information, how likely are you to clean the lint filter and filter housing every 4-5 cycles in the future?	Maintenance	3.6	1.571	0.5	H5
Washing machine	How likely are you to consider using the low temperature setting when laundering in the future?	Energy Efficiency	4.429	4		H3 H6
	How likely are you to consider the size of laundry load when using your washing machine in the future?	Energy Efficiency	4.429	4.429		H1
	Based on this information, how likely are you to use washing machine quick spin cycle to drain excess water from your laundry in the future?	Energy Efficiency	4.6	3.2		H5

Despite reporting a high intention, 8 behaviours were not being performed, or only rarely, 4 weeks after the intervention. This discrepancy between the behavioural intention and actual behaviours is recognised as the intention-action gap. Only the 'engage the auto-defrost freezer function' behaviour was not actioned in any household. This discrepancy from intention to action is primarily because no household reported having identified an auto-defrost function.

The remaining 7 behaviours, that were rarely performed on average (and not performed at all in some households) were 2 energy-efficient behaviours, including choosing to boil water to a lower temperature and selecting a moisture sensing setting when using your tumble dryer. The only households using a moisture sensing setting have smart appliances that automate the selection (H5 and H7). As for kettle use, only 2 of the households have temperature control kettles, and only 1 changes their settings when making different hot drinks (H5). H4 shared that even if they had a temperature control on a kettle, they would not use them because they don't know what needs to be at what temperature. This is a knowledge barrier. Whereas, H1 had expressed an interesting view, which concludes that they would need to see significant cost savings to justify a purchase of a temperature-controlled kettle, a motivation-based barrier, as below:

"I didn't even realise you could buy kettles to boil water at different temperatures! I just assumed a kettle was on or off. Would I buy a kettle like that? Depends how much it is... a basic kettle is going to be £20, but a fancy model temperature one is going to be £40."

"So you need to know that it's going to save you £20 over its lifetime?"

"OR it's going to, like you say, how different is it to have a coffee at a lower temperature? I have a coffee everyday so I could be tempted by that. But if it's £100 vs £20, no chance."

Researcher: what about £60?

"Mm, even that is too much, but I'm a middle at Lidl kind of shopper."

The remaining 5 behaviours are maintenance related. These include descaling the kettle, inspecting the fridge door seals for cracks and splits, and cleaning the microwave and washing machine. Regarding kettle descaling, several households reported having inspected their kettles in the 4-week period, but only 1 descaled. All other households recognise that they should perform the behaviour but blame either not having the resources on hand (i e.g., vinegar), H1 and H4, or accept that it has not been a high priority to complete, H6 and H3. Two households mentioned the unpleasant smell associated with descaling.

The behaviours centred around general cleaning had common comments from participants about being periodic tasks, often only signalled by visible dirtiness. H4 candidly shared that their lack action in cleaning their washing machine is due to lack of time and general inclination to do so. It is important to note that some behaviours are only intended to be performed infrequently, as is the case for fridge door seal inspections. Four households did inspect once, all stating that they did it immediately following reception of the consumer education messages because, as H5 stated, "it was easy." Those who did not inspect 'forgot' (H1) or, in the case of H4, "probably won't get around to it because I won't do anything about it."

Table 7. Behaviours with high intentions but no/rare action taken post-intervention

Appliance	Behaviour	Type of behaviour	Intention (mean)	Action (mean) 1-5 rank likelihood 1-10 times performed	NO. of times performed across households	Type of action	Households performing as NEW
Freezer	How likely are you to engage the auto-defrost function (if available) in the future?	Maintenance	4.333	0	0		
Kettle	How likely are you to descale your kettle in the future?	Maintenance	4.429	0.143	0-1	Affirmed	
Freezer	How likely are you to check if your freezer has auto-defrost function in the future?	Maintenance	4.167	0.143	0-1	Affirmed	
Fridge	How likely are you to inspect your fridge door seals in the future for cracks or splits?	Maintenance	4.286	0.429	0-1	New	H3 H5 H7
Microwave	Based on this information, how likely are you to clean your microwave regularly in the future?	Maintenance	4	1.286	0-4	Affirmed	
Kettle	If you have / had a temperature setting available on your kettle, how likely would you choose to boil water to a lower temperature in the future?	Energy Efficiency	4.286	1.429		Affirmed	
Washing Machine	How likely are you to clean your washing machine in the future?	Maintenance	4.286	2.6	0-10	Affirmed	
Dryer	Based on this information, how likely are you to select a moisture sensing setting when using your tumble dryer in the future?	Energy Efficiency	4.4	2.8		Affirmed	

3.3.2.2 Changes in Energy Usage

Another measurable factor of actual behaviour is statistical changes in the installed appliance energy monitors. Table 8 depicts the difference in average energy use (in kilowatt hour (kWh) per day) in the four weeks pre and post intervention in each household (except for H6 because of energy meter record errors). Notably, no household either decreased or increased use on all their appliances. Of appliances measured, all fridge/freezers and microwaves increased use, whilst kettles and toasters had mixed outcomes.

The greatest decrease in energy use recorded was H2's kettle (-0.098 kWh per day). When reflecting on kettle use, the participant reported that they are vigilant about only boiling the amount of water that they need because, as stated, "I get annoyed because I am wasting energy." This high level of awareness likely contributed to the decrease in energy use over time. Interestingly, conversely, the largest increase in energy usage was H7's kettle (0.037 kWh per day). Unlike H2, H7 states that they always have their kettle full. They do not often use it, so it is more convenient for them to know it is always full when they do use it. They also acknowledge that despite having the option to select a lower temperature when boiling water, they do not. These behaviours likely contributed to the kettle's slight increase in energy consumption.

Using the UK Government's official standard variable tariff average for 2023 of 33.2p/kWh (pence per kilowatt hour) for electricity, this energy use can be translated to costs for the households. The greatest individual saving is 3.25p per day on H2's kettle. This comes to, on average, £0.99 per month, or £11.86 annually.

Evidently, these changes are incremental. The consumer education messages shared are likely to have gradual effects on appliances overtime and this study only addressed a short period of 3 months. It is also important to note that given this short timeframe, general life fluctuations, such as having guests to stay and taking vacations, considerably impact results at the two points of measurement. Despite this, what these results do show us, even in the simple comparison of H2 and H7's interactions with their kettles, is that the decision to perform energy-efficient behaviours, or not, does impact energy use and, ultimately, cost savings. For example, as explained, H2 daily 3.25p savings will result in £11.86 annual savings on their kettle alone, if their behaviours persist. Therefore, there is potential for considerable savings across individual households if these similar savings are multiplied across all appliances.

Table 8. Comparative kWh per day: Difference pre and post intervention

Household	Appliance	Difference pre and post intervention (kWh per day)	Cost saving (pence per day)	Cost saving (£ annually)	Total savings (£ annually)
H1	Fridge	0.020128205	0.67	2.44	-2.66
	Kettle	0.016423077	0.55	1.99	
	Slow cooker	-0.058487179	-1.94	-7.09	
H2	Kettle	-0.097745515	-3.25	-11.84	-13.16
	Toaster	-0.014294352	-0.47	-1.73	
	Fridge	0.003472527	0.12	0.42	
H3	Kettle	0.014069767	0.47	1.70	2.75
	Microwave	0.000772868	0.03	0.09	
	Toaster	0.007886047	0.26	0.96	
H4	Microwave	0.000697183	0.02	0.08	-0.81
	Kettle	-0.001502817	-0.05	-0.18	
	Toaster	-0.005887793	-0.20	-0.71	
H5	Toaster	-0.026572222	-0.88	-3.22	-3.78
	Kettle	0.008277778	0.27	1.00	
	Coffee Maker	-0.014005556	-0.46	-1.70	
	Food Mixer	0.001138889	0.04	0.14	
H6	Coffee Machine	N/A	N/A	N/A	
	Kettle	N/A	N/A	N/A	
	Microwave	N/A	N/A	N/A	
H7	Kettle	-0.034087287	-1.13	-4.13	-4.75
	Toaster	-0.042203985	-1.40	-5.11	
	Microwave	0.037126186	1.23	4.50	

3.3.3 Preferred Channels to Receive Consumer Education

The participants expressed a variety of channel preferences for how they would like to receive information about how to interact with their appliances to save energy and prolong appliance lifespans. The most frequently requested channels across all appliances were WhatsApp, dedicated websites, and manufacturer newsletters, all at 13% (Fig. 10). Importantly, 15% of responses explicitly recognised a desire to receive the information at the point of purchase of the appliance.

Table 9 shows the preferred consumer education channels specified by each household for receiving information about energy efficiency and product life extension behaviours. Notably, the study recordeda variety of preferences across the different households, as the diverse consumer routines and personas mean they have individual affinities to a ray of channels. An example of the varying preference was captured in participants responses. For example, contradicting statements were recorded in two households where H2 explicitly stated "I like traditional TV ads", whilst H1 queried, "who looks at TV ads anymore?"

Figure 10. Channel Preferences to receive appliance education

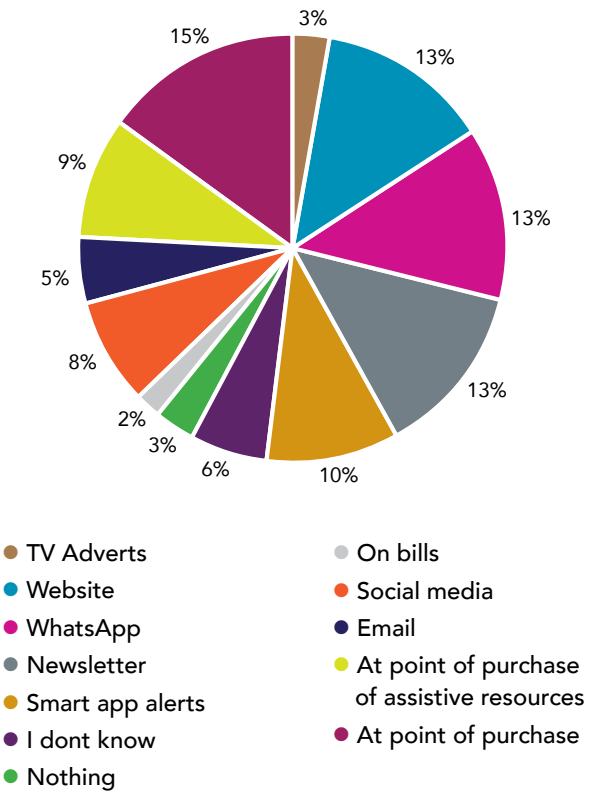


Table 9. Consumer Education Channel Preferences by household

Household	Preferred Platform	Secondary Platform(s)
H1	Social media	Doesn't know, TV programme
H2	Doesn't know	Social media, TV advert, Email, Nothing
H3	Website	
H4	At point of purchase	At point of purchase of assistive resources
H5	WhatsApp	
H6	Newsletter	
H7	Smart app alerts	Email

4.0 Discussion

4.1 Use Education to Influence Consumer Behaviour at Home

4.1.1 Education Can Influence Consumer Intentions

Knowledge is a key driver of consumer decisions. As demonstrated by the study, consumer education is influential in introducing and motivating participating households to perform energy-efficiency and product life extension behaviours (see sections 3.1.3 and 3.2.3). The consumer education messages affirmed the environmental and cost-saving benefits as key motivational factors driving the energy-saving behaviours. Meanwhile, any explicit reference to these two motivational factors were not identified as key reasons to maintain appliances. Most notably, maintenance behaviours were primarily motivated by the ability to increase appliance longevity which positively influenced the intention to do so, as it doubled across the sample post-intervention. A new motivational factor was reported by participants post-intervention, which was there being a 'sufficient and apparent benefit to make the effort worthwhile'. Nonetheless, an increase in appliance longevity is interrelated with the two motivational factors explored in this study, as it results in economic benefits (e.g., delayed need for purchase of new appliance replacement) and environmental benefits (e.g., delayed appliance disposal).

Aside from the economic and environmental benefits driving consumer behaviour, the study identified there are other motivational factors driving energy efficiency, such as appliance features that enable versatile use (e.g., microwave capability to cook meals participants normally would use oven for), ability to maximise appliance utility (e.g., washing machine used to full capacity of space) and having the confidence in good end result (i.e., optimal appliance functionality).

As demonstrated in this study, new knowledge gained through consumer education messages can improve the perceived capability to perform resource efficiency and product life extension behaviours. An example from the study is H1 who pre-intervention noticed that their hob's burners were dirty and needed cleaning, however due to being weary to interact with a gas-consuming appliance they had not pursued the maintenance behaviour, despite their desire to have a clean hob. Four weeks after receiving the consumer education messages, H1 shared:

This demonstrates the important role education plays in empowering consumers to enact resource efficiency and product life extension behaviours, whilst mitigating their risk aversion associated with lack of knowledge on best practice. In this example, the knowledge acquired through education improved participant's perceived capability, which has led to their increased intention and action for the target behaviour.

4.1.2 Knowledge Alone is Not Enough to Mitigate the Situational and System-level Barriers

The study demonstrates that despite having positive intention to perform both energy efficiency and product life extension behaviours, the provision of knowledge alone is not enough to ensure or determine that consumers can adopt these behaviours, and other system interventions are needed to mitigate the situational and system-level barriers.

Participants provided a ray of situational and system-level barriers to them performing target behaviours. ***Despite having positive intentions, the performance of target behaviour was deemed difficult or challenging.*** Example reasons for this

revolve around the way their daily lives and routines are structured and include self-proclaimed lack-of time or laziness (H5, H6), lack of prioritisation (H1, H3, H7), and importantly, there being a lack of the necessary assistive resources on hand (H1, H4). The barriers to performing the target behaviours, can also be attributed to the ***macro-level context of the cost-of-living crisis.*** These include, simply 'forgetting' (H1, H2, H5) to perform behaviours because of other critical priorities, as well as the fact that potential return on investment (ROI) of time, money and effort was not deemed worthwhile compared to other routine behaviours.

Interest in ROI was a recurrent theme in participant responses. For example, H7 shared that savings from changes in appliance-use behaviours are "trivial compared to £30 cost of heating daily". The need to be sufficiently rewarded for behaviours is reflective of the high-pressure macro-level societal context as households are weighing up behaviours, not exclusive to appliance use, that will ultimately result in long-term, individualised benefits. When asked if participants considered the potential extrapolated benefits to broader society (e.g., incremental change in cost/energy per household for behaviour changes, but wide-scale impacts across 27 million households in the UK) there were mixed responses, showing that the perceived importance of these factors varied across the sample. Some participants recognise that the savings can 'add up' (H2, H4, H3), but this perception does not always lead to consumers taking on the target behaviours. Others maintained that the greater motivator of their behaviour is there being a guaranteed saving or benefit associated with its performance, which can span over the participants'' own lifetime (H6, H7). This speaks to the intensely individualised nature of our society, which influences our decision to behave for the good of our immediate interests versus collective society.

4.1.3 There is an Intention-Action Gap

Despite there being a positive intention to enact energy efficiency and product life extension behaviours recorded post-intervention, several barriers, including those that are situational (e.g., routines) and systemic (e.g., availability of resources) have impacted the performance of target behaviours in the long run. This highlights the intention-action gap, a concept described in behavioural economics which poses that there is a difference between what people say they would like to do, and what they actually do. The intention-action gap has been identified as a common occurrence, especially in the context of pro-environmental behaviours, as discussed in an energy-consumption based study by Lee et al. (2020).

Having identified the barriers that play a role in the intention-action gap in this specific context is important, as they can be taken into consideration in future appliance-related education. The intention-action gap can be bridged by addressing 1) routine-related and 2) system-level contextual barriers, both of which occur in the volitional phase. The volitional phase is the pivotal point when someone has set an intention but is yet to follow through with the behaviour. For instance, in the case of this study, the time between a) when the participants read the consumer education messages and reported back on their intention to carry out recommended actions, and b) the second round of household visits when they shared what actions they did (or did not) follow through with.

Addressing Routine Barriers through Consumer Education

Education allows consumers to better understand the logic behind their decisions. In the decision-making process, however, this rationality is often overshadowed by habits, which act as the baseline for individuals' behaviours. Brette et al. (2017) suggests

"human rationality appears bounded by the cognitive and behavioural rigidities of man, namely, to a large extent, by habits". This phenomenon is exacerbated in the household context, as "once householders adopt a convenient practice and become familiar with it, they are unlikely to change it" (Lee et al., 2020). This is exemplified by H7, who only wanted to use their dishwasher and washing machine in the evening to ensure a clear schedule for their busy morning routine with their child. This was seconded by H3's decision not to utilise night-time tariffs because they do not want to run their washing machine late at night.

The tension between intention to behave in alignment with the consumer education messages and natural compulsion to stick to habitual routines ultimately leaves households failing to follow through on performing the recommended activities. Borrowing from studies of physical exercise intention-action gaps (Sniehotta, Scholz and Schwarzer, 2005), it is important to target the volitional phase (between setting intention and performing the new behaviour) by encouraging and assisting in 1) action-planning, and 2) increased self-efficacy. Action-planning gives people something to rely on as one can visualise a situation in which they perform the new behaviour knowing the "when," "where" and "how." Coupled with an increased sense of personal capability despite self-imposed routine-based barriers, as previously presented, this aids in minimising the gap. For example, H6 expressed that they ultimately did not clean their washing machine because their partner knows how to do it. H6 stated that, "if it were me, I would have had to read the manual; she [their partner] didn't have that barrier." This is a great example whereby ***consumer education messages can better equip consumers to action-plan, so they don't feel unknowledgeable and incapable of performing the behaviours in the future.***

Addressing Macro-level Barriers through Consumer Education

There are two recommendations to counter the barriers attributed to system-level factors. The cost-of-living crisis brings an array of system-level barriers to performing the energy efficiency and product life extension behaviours. For example, reported 'forgetting' to enact a target behaviour is due to other more pressing priorities, or is hindered by the low perception of there being enough ROI for the behaviours to be worthwhile. First, there is a general need to minimise the temporal distance between the reception of information and the ideal performance of behaviour (Lee et al., 2020). To cut through other macro-events that are taking up mental space, it is important that messaging is accessible at the exact moment when it is needed. One example of this could be minimising the temporal distance between consumption of energy and seeing the cost (e.g., in the monthly electricity bill). This can be countered with mechanisms such as the smart meters that display environmental and economic cost of consumption on demand. Another example could be a recurring post-purchase consumer education newsletter, reminding and instructing maintenance behaviours at regular time intervals, such as the provision of reminders and instructions to clean the oven at 3-month intervals. ***Making information more timely and readily available is likely to put the behaviours front of the consumer mind and less likely to be forgotten.***

Second, consumer education messages can be tailored to clearly distinguish between low, medium and high effort behaviours and explicitly acknowledge their respective ROIs, whether it be in the form of time, money, or other benefits. For example, Rahman et al. (2010). categorises energy "conservation measures according to their associated level of investment into zero investment measures, minor investment measures and major investment measures".

The specification of effort required to perform the behaviours require can enable educators (e.g., industry organisations and policymakers) to distribute relevant information via appropriate channels at the most suitable and relevant moments on the consumer journey. For example, identifying 'cleaning the oven' as a high effort behaviour will ensure educators share detailed timely information and are explicitly calling out the immediate and long-term benefits (e.g., email alert with text and visual communication elements as mediums to explaining how, when and why consumers are required to perform energy efficiency and product life extension behaviours).

In summary, consumer education is a necessary and powerful enabler of behaviour change as it motivates human intentions by targeting the psychological determinant of their behaviours, such as the economic and environmental values or the perceived capability associated with the performance of target behaviours. ***There are several consumer-intrinsic (e.g., psychological) and extrinsic (system-level) barriers that must be considered and addressed simultaneously by the consumer education to ensure it is effective.***

4.2 Aligning Appliance Design and Consumer Education to Increase Resource Efficient Behaviours

Consumer education about appliance functionality in parallel with a continuation an expansion of standardised eco-design principles can empower and enable consumers use their appliances in a resource efficient way. In general, appliance capabilities for resource efficiency are not understood and underutilised by the consumers, with eco-settings specifically being perceived as confusing for consumers. Consumer education can be effective for addressing these barriers however, an inconsistency and variety of information about appliance capabilities to achieve resource efficiency currently available to consumers (e.g., online) causes confusion and leads to inaction.

4.2.1 Appliance Settings are Underexplored and Underutilised

Electrical household appliances, particularity the new generation models, offer the consumer with an array of operational settings (e.g., wash programmes) they can choose from when interacting with and utilising those appliances. However, it is common that available appliance settings are unexplored and underutilised by the consumers, as they tend to use only one or two settings that they perceive work well in facilitating their daily needs (e.g., laundering, cooking, dishwashing).

> "Yes there's a [setting] called 'superwash', which I don't know what it does. It just means it uses more water maybe? And there's extra rinse, which I would have thought is more water…I always find I just use one or two settings and that's it. You don't really explore all the options."

> "I've not tried settings like Daily Wash, which I think are quicker. Again, it's like 'if I have used that setting, [I know] that setting works'. If it works, then I'll leave it – I'm not going to play with it"

Despite having information available in user manuals provided upon purchase and being accessible online e.g., from appliance providers, consumers rarely explore their appliance settings, often missing out on an opportunity to optimise the resource efficiency facilitated through some of these settings. Once consumers establish one or two settings that work well for them, they occasionally adjust an operational factor (e.g., temperature change) but overall tend to stay

within their established habit of using their preferred setting. One key reason consumers resort to changing their habit of interacting with an appliance is if they find a compromise in function (e.g., dishes suddenly not being properly cleaned when using a preferred dishwasher setting), or they occasionally divert from their normal choices to use another appliance setting (e.g., various operational temperatures are chosen outside of normal routine depending on the context, such as when washing types of textiles or baking specific dishes,).

Consumer education provides an opportunity to influence behaviour and help form new habits. After receiving consumer education messages, participants expressed intentions to try other settings, especially lower temperature settings, and some reported that they enacted the intended behaviours with an aim to stick with them and incorporate them in daily routines as a new habit.

It is however important that there is an alignment between the content that is provided in the consumer education messages and the technical capability of the appliance. For example, through the study participants identified and reported that an option to choose a low temperature washing setting on a washing machine can only be facilitated through choosing a few specific wash settings e.g., 'cotton', 'synthetics', or 'superwash', which was a feature they were unaware of. The lack of information about appliance capability and steps required to achieve recommended behaviours was reported by participants as a barrier. This highlights there is a need for guidelines on how to design the content of the consumer education so that it can address the varying appliance capabilities.

4.2.2 Eco-settings Require Education

In recent years, UK eco-design legislation has required certain appliances to have incorporated eco-settings (legislation.gov.uk, 2021). These are especially effective where they are a default setting, reducing the consumers need to actively select it. However, participants showed that the presence of an eco-setting, even as the default, did not guarantee its use. There was significant confusion around eco-settings, especially in the context of their benefits e.g., what they saved - energy, water, or both., with the notable characteristic of eco-settings being a longer cycle time. Longer cycles were reported by participants as associated with higher energy use, causing confusion about 'eco-friendliness' claims of the eco-setting.

> "Now, this is the bit I'm always unsure about. I put it on an eco-wash but eco-wash is 3.20 hrs and speed-wash is an hour, so I don't know what the eco-wash is saving,. Presumably water but I'm not sure. Does it save energy because it's heating it less? What's eco about it? Is it eco in that it's saving the planet? Or is it saving me money? I don't really know"

> "I can use my washing machine well but have always wondered whether a 3-hour eco-wash really is more environmentally friendly than a 1-hour speed wash"

> "I don't know what the 'eco' means. I just know it takes longer."

Consumer education about how eco-settings work can be a powerful tool to reduce confusion, create clear incentive for use, and inform the need for varying time and temperature settings, such as in the case of washing machine and its long cycle eco-setting. As demonstrated in this study, this knowledge can help consumer decisions to incorporate eco-settings into

their daily routines. After receiving the consumer education messages explaining the function and the benefits of eco-settings, participants reported that they were more likely to consistently choose eco-settings for appliances, such as the washing machines.

In the context of appliances other than washing machine, participants often reported an absence of eco-settings, which they perceived as the main route to saving energy or water. This implies, consumers lack knowledge on how they can save resources when using their appliances in instances when their appliance has no explicit 'eco-setting' option incorporated in its design.

While eco-settings combined with consumer education were shown to increase resource efficient behaviours, there are other appliance features that participants reported to be confusing and hinder their resource efficiency behaviours. An example is the presence of symbols that vary across appliance types and brands participants lack the understanding of, setting labels wearing off with use and time, and ambiguous symbols, all of which make it difficult for consumers to understand the capability of their appliances to run most efficiently. For example, after receiving consumer education about adjusting fridge temperatures to an optimal temperature, participants opened their fridge doors to find a dial that read 1-5 (see Fig. 11) but they could not tell intuitively if these numbers represented degrees, or whether 1 was the coldest setting, or the warmest. In this example, the interpretation of labels acted as a barrier, despite them holding and demonstrating a positive intention to change their fridge settings. One participant also reported there being an alternative labelling system (a scale of increasing sizes of snowflake), which misaligned with the content of the consumer education messages that instructed adjustment based on numerical labels. There is a diversity and ambiguity of these settings and the mismatch between the consumer education messages and appliance options. ***When designing appliance interfaces, brands need to consider consumers lack of knowledge despite the information being readily available in manuals), and although some labelling schemes appear intuitive, there remains confusion and incorrect interpretation of appliance settings.*** By improving the labelling schemes, we can enable consumers to understand their appliances better and ultimately empower them to performing a target behaviour correctly and with confidence.

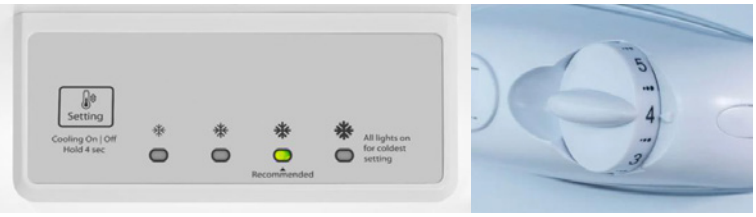


Fig 11. Examples of appliances settings consumers found confusing in relation to education messaging.

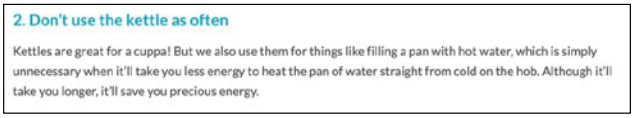
4.3 Need for Common Language and Varying Delivery Channels

4.3.1 Consistency in Communication

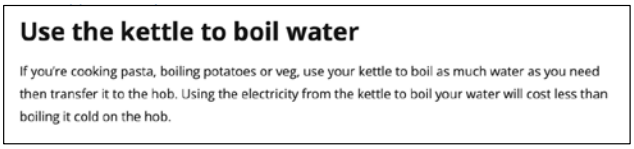
The process of designing the consumer education messages that were administered to participants in phase 2 of the study (as a behaviour change intervention) involved the research team taking stock of the current consumer education content available online (e.g., manufacturers, government, repair and maintenance services, associations, and consumer advocacy groups' websites). In developing these messages, efforts were made to provide information that came from trustworthy sources that offered credible information on the claims associated with the environmental and economic benefits of performing various resource efficiency and product life extension behaviours that were subject of the study.

The review of current consumer education available online found the information conveyed in the messages to be inconsistent and varying. The review found in some instances the information contained in the messages was inaccurate, weak or potentially confusing to consumers risking being perceived or interpreted as lacking credibility. The current consumer communication on maintenance predominantly focused on cleaning actions, the benefits of which and 'how-to' were typically well-explained. While, the high-effort actions were also reasonably explained, the associated benefits of performing them were vaguely described or completely lacking (e.g., inclusion of vague references to appliances 'lasting longer'). An example of where participants of the study encountered contradictory and potentially confusing information were consumer education messages online about how to boil water in the most energy efficient way, (see example messages in Fig. 12).

Figure 12. Example contradictory messaging taken from two providers advising online on best practice cost/energy saving behaviours.



Source: Appliance City



Source: Leicester Mercury

This demonstrates a need for information provided to consumers to adopt a common language, particularly to ensure it is clear, informative and accurate in order to motivative the consumers to adopt energy efficiency and product life extension behaviours. Industry organisations and policymakers involved in developing and disseminating consumer education should collaborate to create standards or guidelines for effective communication.

Structure and Format

Various approaches to consumer communication have been explored in past research and campaigns, specifically in the context of the elements of a message. For example, Ajzen (1991) outlines a structure for effective messaging which includes content that presents an advocated position, a set of general arguments supporting the advocated position, both of which are followed by factual evidence designed to bolster the general arguments. In addition, specifying behaviours in messages (such as 'the use of eco-setting on your dishwasher') alongside an economic (or environmental) benefit resulting from its performance (such as 'this can save £X per year') is more effective than using general statements (Casado et al., 2017).

Furthermore, and as demonstrated in this study, ***visuals in the form of photographs and videos are instrumental in informing the performance of behaviours that are unfamiliar to consumers, especially for the product life extension which are seldom performed.*** Despite playing a key part in consumers' daily routines, the level of understanding of how they function is low. Visuals have been reported by participants as helpful for them to become familiar and knowledgeable enough to pursue a behaviour that is new to them. This therefore mitigates the hesitancy to disassemble or interact with appliance components in order to maintain them, especially when visuals can be used to guide safe conduct thereby reducing a perception of danger that halters the performance of the behaviours (e.g., maintenance perceived as risky). In addition, the study observed that visuals can serve as a social norming tool e.g., participants' seeing another household resident perform an action provided them with comfort that a behaviour is acceptable.

Motivation and Benefits

Even when both specificity and effective structure were present, the actual economic benefit of suggested actions was not motivating enough for participants to adopt new behaviours, especially when some of them compared the savings to the significantly higher cost of heating their homes. In this case, addressing how we frame economic benefits is important, and grouping cost savings or lengthening timeframes to increase the extent of impact can help (e.g., money saved over a year, versus one month).

As reported by participants, consumers need to be aware of the tangible benefits to feel motivated or incentivised enough to perform resource efficiency behaviours, especially those which do not have immediately noticeable results, such as the preventative maintenance activities. Nonetheless, investing time, effort, and resources to prevent the future breakdown of an appliance challenges the bias of human preference of short-term rewards (even if small, over long-term gains (Hardisty and Weber, 2009). Additionally, the 'jobs' of product maintaining can feel meaningless since it is difficult to immediately tell whether they are effective, with larger behavioural changes to an established routine needing greater incentives.

> "I would say things that are quick, things where you can feel or see a difference [are worth the effort]. So, when you take gunk out of the bottom of washing machine you can really tell the difference. Whereas [cleaning] the back of the fridg -, I just won't feel like there's any difference [by me performing a maintenance behaviour] I need a [noticeable] validation when I do a job.

Providing both, short-term rewards for carrying out maintenance and the provision of accurate information about how maintenance contributes to the extension of appliance lifetimes is helpful for motivating consumers to follow through on preventative maintenance activities. Currently, the available maintenance messaging is perceived by participants as weak to influence them to action. Rather than implementing vague statements about increasing appliance lifespans, consumers need to know in detail what regular maintenance means for them and their appliances (e.g., a specific amount of energy saved, appliance lifetime extended by a specific number of times, improved function, time saved). In addition, consumers need assurance that resource efficient behaviours do not compromise appliance function. For example, the study found that in the case of eco-settings, the assurance that results of using that setting are similar to when using other settings, helped to reduce uncertainty about trying something new.

Tailored Consumer Education based on Appliance Type

Participants recorded that they prefer education that is specific to their own appliances. General statements about potential savings based on average or common appliances were doubted because consumers did not know how these applied to the specific brands and models of their own appliances. For repairs and maintenance specifically, participants reported that directions on their specific make and model help provide assurance that they were doing things correctly.

Message Credibility

Including the sources of information in a consumer education message can increase its credibility. For this study, reliable sources were listed underneath each message with links for further exploration. Participants reported that this helped to add credibility to the messages and were more likely to trust academic or industry sources. The academic and industry sources were perceived to provide expert knowledge. Academic sources specifically were trusted due to there being no underlying motivation to sell additional products or services (as in section 4.4.2).

Example Message

Examples of effective messaging, using the suggestions above, could be structured as below:

"You can help make your dishwasher last longer by using the dishwasher's 'care cycle' (advocated position). Performing the care cycle on your dishwasher every month (or when prompted) can add X cycles to its lifetime, which can help avoid the purchase of a replacement for another one for additional X years (set of general arguments supporting the advocated position, concrete motivators). The care cycle runs at a higher temperature than the auto setting which helps to clean food particles and other build-up. You can also add a cup of vinegar to this cycle (upright in the bottom drawer) to tackle any limescale inside hoses or pipes (factual evidence designed to bolster the general arguments). You might not see any immediate changes (common doubt), but if you do this regularly, your dishwasher will function better, smell better, and will last longer (tangible, immediate reward coupled with long-term benefits)!"

4.3.3 Customised and Varying Delivery Channels

While messaging for consumers needs to be consistent, the channels through which consumers prefer to be educated are diverse. The sudy found no agreement on the best medium through which to receive information. In contrast, the findings showed that participants had unique and varying preferences which contradicted each other (see section 3.3.3). Thus, ***for consumer education to be effective, a variety of channels for message delivery should be used to ensure the content reaches and is received by the consumers.*** These delivery channels include but are not limited to, WhatsApp messaging, council newsletters, emails from manufacturers, manufacturer websites campaigns or education sections, and reminders to phones disseminated via apps.

Importantly, participants reported they want to be educated at point of purchase about how to use and maintain their appliances in a resource efficient manner. There was also emphasis put on the need for reminders and participants reported they were more likely to perform action upon receiving the reminders in the same room as as where their appliances are used.

4.4 Repair and Maintenance Education can Influence Consumer Behaviour

4.4.1 Repair and Maintenance Education

To reduce environmental impacts, industry organisations and policymakers need to empower consumers to extend the lifespan of their appliances. While the knowledge about appliance maintenance and repair is currently low among consumers, the study demonstrates that they desire to be able to carry out these behaviours. Participants reported, they find appliance replacement a costly hassle, want to avoid waste (landfill), and want to avoid interruptions in use caused by appliance breakdown. Furthermore, they are motivated to attempt DIY repairs to avoid paying for something they could feasibly do themselves, and some even enjoy the challenge.

Consumer education showed to be helpful for increasing knowledge about the product life extension behaviours and enabled participants to solidify the connection between appliance maintenance behaviours and how these facilitate appliance longevity. This matters for physical longevity, but also for emotional longevity since appliances that are not kept clean are thought to be less effective and are less likely to be repaired (Harmer et al., 2019). Repair knowledge can lead to better care and help consumers understand when to attempt repairs themselves or use professional repair services (Laitala et al., 2021).

Manufacturers are required to provide repair and maintenance information in appliance manuals and online (legislation.gov.uk, 2021). However, consumers tend to refer to manuals occasionally and only when they have specific problems. Enabling consumers to repair and maintain their appliances require greater efforts from industry to effectively get the right information in front of consumers, outside the provision of information in printed manuals they receive only once, upon appliance purchase.

4.4.2 Consumers Hesitate to Trust Industry Repair and Maintenance Messaging

As demonstrated in the study, participants expressed suspicion towards manufacturers messaging about repair and maintenance. "Planned obsolescence" was quoted by few participants who assumed that manufacturers are not truly intending to encourage repair and maintenance activities. The vagueness of information about repair and limited options for repair were deemed as barriers to participants trusting the authenticity of manufacturer messaging. Participants also associated manufacturer-approved repair services with inflated prices compared to independent repair services.

> "You get sent to manufacturers websites and part of me is thinking - you want it to break because then you'll make more money. But, when I got there I saw they genuinely are trying to help people look after what they've got."

> "Manuals should tell you what you can repair yourself. At the moment it appears that you can't repair anything yourself, and that's just not true, I'm sure! So it should be in the manual and there should be clear instructions."

Consumer education presents an opportunity for industry organisations and policymakers to build trust and loyalty with consumers through the provision of robust information about appliance maintenance and repair. Instructing consumers to extend the lifetime of their products can support industry claims that they are serious about reducing the negative environmental impacts associated with their products, which can bolster brand image and customer loyalty.

4.4.3 There Remain Many Barriers to Repair and Maintenance

Perceived Barriers to Repair

Lack of knowledge is not the only barrier to performing product life extension behaviours, such as repair and maintenance. Other barriers commonly identified in literature are also financial costs, lack of time, and lack of tools or skills (see Laitala et al., 2021; Table 10).

Table 11 presents a list of the perceived barriers to repair reported by participants in this study. They corroborate previous findings and are divided into categories based on the method of repair.

Table 10. Barriers to repair (adapted form Laitala et al., 2021; McLauren and McLauchlan, 2015)

Barrier Type	Example
Practical	convenience and access to materials or skills
Social	not wanting to use visibly mended [products] in order not to appear impoverished
Socioeconomic	varying availability of money for repair
Systemic	structural barriers to establishing a repair business, limited availability of original spare parts and manuals, lack of suitable education to learn repair skills
Psychological	lack of emotional attachment to a product or the desire for a new one

Table 11. Perceived repair barriers reported by participants

Method of Repair	Barrier Type
DIY Repairs	
Lack of knowledge (for diagnosis and repair)	Practical
Poor or conflicting information	Practical
Lack of accessible parts	Systemic
Perceived Danger / Industry discouragement of amateur repair	Practical/Systemic
Repair Services	
Cost of repairs (generally, and in relation to a new replacement)	Socioeconomic/Systematic
Reliability of repair	Practical/Systemic
Inconvenience of multiple home visits	Practical
Effort to find the right person	Systemic
Lack a quality guaranteed on replacement parts	Systemic
Product out of warranty period	Systemic
Repair Café	
Lack of awareness of them	Systemic
Limited to small appliances (due to transport)	Practical
Repair (generally)	
Age of appliance (perceived to be nearing end of life)	Psychological
Appliance breakdown indicating perceived end of life (i.e. repair not worthwhile)	Psychological
Kitchen remodel (desire for different aesthetic or function)	Psychological/Social
Condition of appliance (dirty, cosmetic damage)	Psychological/Social/Practical

Consumer education can help change the perception of the practical, social, and psychological barriers, but systemic and socioeconomic barriers need to be addressed through other routes, such as by legislation, policy, and led by industrial organisations. In addition the repair options also need to be widely available, affordable, reliable, and convenient to the consumers for them to adopt.

Perceived Barriers to Maintenance

Barriers to maintenance reported by participants include lack of knowledge, and a disconnect between maintenance behaviours and appliance longevity. Consumer education improved both of these factors, nonetheless participants still struggled with some physical barriers they faced when attempting maintenance behaviours (e.g., integrated appliances). Another barrier to maintenance behaviours was lack of assistive resources on hand. For example, a barrier to descaling the kettle was not having vinegar (or another descaler) available for use.

A recurring theme when asked about appliance maintenance was the mentality that if the appliance functioned well, maintenance was not required. Thus, preventative maintenance was often forgotten or deemed unnecessary. An exception to this rule were appliances that had 'smart capabilities' and could prompt consumers to run a care cycle.

> "I tend to operate on an 'if it ain't broke, don't fix it' model."

Other prompts for maintenance behaviours reported by participants included tangible cues such as a loss of function, visible uncleanliness, unusual noises, or an unpleasant smell. However, these tangible cues are often symptoms of misuse or neglect, so consumers need further education about what to do to prevent them from occurring.

Researcher: Are there any actions that you would be most likely to do?

> "I would say things that are quick, things where you can feel or see a difference. So when you take gunk out of the bottom of washing machine you can really tell the difference. Whereas with the back of the fridge, I just won't feel like there's a difference… I'll do things that are quick and have the feeling of immediate satisfaction."

Despite participants consistently reporting that appliance longevity was a motivator for carrying out maintenance behaviours, consumers need assistance actioning their intentions. Assistance can come in the form of reminders to maintain appliances (addressing psychological capabilities), accompanied by concrete potential results to motivate action. Carrying out maintenance actions that had no noticeable result left participants wondering if their actions had any effect on the longevity or functionality of their appliances. Assurance that these routine actions would lead to appliance longevity expressed in concrete and meaningful terms could act as a motivator for consumers (e.g., a specific number of further use cycles, added months/years of use, better performance). Additionally, avoiding the hassle of appliance malfunction or the need for purchasing a replacement was also reported as a motivational factor.

4.5 Smart Technology and Resource Efficiency

One study participant owned several smart household electric appliances integrated with smart technologies deployed within their home (e.g., digital home assistant). Their kettle, washer/dryer, and dishwasher all had smart capabilities and offered this study a unique chance to observe how these technologies affected resource efficiency at home.

4.5.1 Energy-saving Capability

The smart capability of the washer/dryer meant that the resource efficiency was achievable through technology because these appliances were able to weigh the contents inside them, add the appropriate amount of energy, water and detergent, and automatically use moisture sensing to determine drying time. The participant assumed the dishwasher was working optimally since it had sensing capabilities, nonetheless it routinely operated at high temperature (70 degrees) for each cycle. Following the consumer education messages, the participant reduced the operational temperature (to 50 degrees). Their kettle was reported as almost always boiled full of water and at 100 degrees, even in instances when a small amount of water was needed, and it had the option of a lower temperature setting. The participant routinely used the voice-activated operation of the kettle which was pre-set at 100 degrees and typically used the water for cooking on the hob, always assuming this required a full boil.

This observation makes evident that smart technology in appliances offers the opportunity for energy saving to occur, and that consumer education can increase the technological capability and adjust it to maximise the resource efficiency. Nonetheless, the presence of technology alone is not enough to ensure energy savings (Ozaki and Shaw, 2014). Consumers require the knowledge and motivation to use the technology to its full energy-saving capacity.

4.5.2 Maintenance and Repair Capability

As previously discussed, prompts from smart appliances to run maintenance cycles proved very effective for ensuring action. These prompts referred to regular actions that occurred every few months (depending on how many cycles had been run) and were reported to be easy to comply with. However, for more frequent maintenance activities (the performance of which should occur daily or weekly), it is unknown if these prompts would be seen as irritating or too disruptive to regular routine.

> "It insists that I do the drum clean periodically and it won't actually let me do anything until I've done that. So there's a message on the screen, my phone and watch, telling me I need to do a drum clean at 70 degrees when it's empty. It's 'enforced maintenance'...I haven't actually tried to ignore it; I feel that I have to from the messaging. It's only once every couple of months so it's not a hassle and I just do as I'm told."

While built-in reminders, scheduled care cycles, and automated delivery of assistive resources act as enablers for consumers to carry out maintenance and increase longevity, they also currently increase the complexity of appliances by adding additional smart technologies (electronic displays, sensors, etc.). These, in turn, were noted to decrease the perceived repairability of an appliance. Consequently, while smart technologies can aid in lengthening product lifespans through regular maintenance activities, a loss in function of these parts may result in premature obsolescence of the appliance, especially when its owner perceives it as difficult to repair.

> "Because they're so advanced with the AI and voice controller, a repair I could do would have to be something really basic, like this thing has snapped and I need to pop a new one in. I can't imagine a situation where there's something that's broken that I would be able to fix without a lot of skill and research..."

This implies a greater need for affordable, convenient repairs to be made accessible to consumers, but it also requires further development of repairability criteria in the design stage, and a method for determining the appropriate trade-offs between energy-saving, maintenance, and repairability.

4.5.3 Lack of interest in Smart Technologies

The desire to obtain smart technology is not common. Participants showed a wide range of acceptance towards smart appliances, but several explicitly reported that they did not want complex technologies at home, citing reasons such as increased price for perceived small gains and not seeing a functional need for it. Appliance providers tend to focus on new technology as an environmental solution (Ozaki and Shaw, 2014), which is not wholly misguided since new technologies offer significant opportunity for achieving resource efficiency at home (Pakula & Staminger, 2010). However, appliance lifetimes are estimated to be between 5-20 years and the cost of replacement is steep, especially amid a cost-of-living-crisis; this means that many older appliances will be in use for several years to come. It is important to account for this and to communicate how to maintain and use appliances incorporating various types and generation of technology so that they continue to last and can be used by the consumers as efficiently as possible.

5.0 Conclusions and Recommendations

Consumers in the UK today are faced with two major crises: the climate crisis and the cost-of-living crisis. Their appliance use and care behaviours have an important role to play in mitigating the effects of both. Resource efficiency, saving energy and extending product life, can contribute to reducing the environmental impact of the domestic electrical appliance industry whilst helping consumers to save money on the cost of energy and premature appliance replacement. However, consumers are not equipped with all necessary capabilities, opportunities and motivations to reap these benefits.

This study has analysed the role of consumer education as an effective intervention for increasing domestic appliance resource efficiency in UK households. By observing household routines, such as laundering, cooking, and boiling water, researchers established a set of baseline behaviours and then introduced a series of educational messages to measure how they affected consumer behaviours. Results show that consumer education is an effective tool for increasing resource efficiency and should be considered as an important lever for reducing household energy use and extending product lifetimes.

Current consumer education has significant room for improvement and there are other barriers to action that need to be addressed. Solutions must come from the collaborative efforts of industrial stakeholders (brands, designers, retailers), trade associations, and government in conversation with consumers. There is a clear desire from consumers for these stakeholders to act in response to the crises and mitigate the effects with the informed adoption of effective energy efficient and product life extension behaviours. The necessary industrial knowledge and tools are available, and consumers are evidently willing to listen and action best practice.

The following recommendations are addressed to these actors as a starting point for future work:

EDUCATION

Optimise education intervention by enacting the following:

- Collaborate to create standards for effective consumer education, using the suggested structure/format/motivations as a starting point.
- Bridge the intention-action gap by addressing routine-related and macro-level contextual barriers in the volitional phase (between setting intention and performing a new behaviour).
- Assess and develop current channels of education; aim to expand channel diversity to increase reach.
- Develop a communication system for reminders to consumers for resource-efficiency actions (especially maintenance); make information more timely and readily available to reduce the intention-action gap.
- Capitalise on consumers' increased likelihood of adopting repair habits in times of economic downturns by developing more repair and maintenance education to build trust and enable action.
- Align consumer education with the specific appliances consumers have in their homes to avoid confusion.

APPLIANCE DESIGN

Consider appliance setting design:

- Continue to make eco-settings the default setting and expand to other appliances, making sure to educate consumers about setting characteristics to enable informed decisions.
- Design displays, dials and settings with consumer education in mind, reducing confusion by including clear explanations of settings and symbols so consumers know what their settings do without having to reference a manual.

Continue to improve design for maintenance and repair:

- Continue creating tangible prompts and reminders for maintenance actions; ensure high-effort jobs have built-in rewards and preventative maintenance actions are linked to short-term rewards and concrete long-term benefits.
- Prioritise emotional and physical durability in design to create products that intrinsically encourage consumer to repair rather than replace. Refer to the Emotional Durability Design Tool (Haines-Gadd, 2018) as a reference guide.
- Continue to design for increased modularity, repairability and maintainability in future appliance design to aid in consumer capability to repair, and to reduce cost of repair services; repairability is a selling feature in which an increasing number of consumers are willing to invest (Sabbaghi et al., 2016).
- Develop criteria for navigating the trade-offs between repairability and maintainability to add to the product repairability index (see Ruiz-Pastor and Mesa, 2023).

REDUCE SYSTEMIC BARRIERS

Enable consumers to choose repair and maintenance opportunities:

- Encourage emotional attachment to appliances to increase consumer desire to repair. This needs to be supported by a more viable repair economy (see Laitala et al., 2021). Consider policy and legislative levers that make repair more readily available, affordable, reliable, and convenient; these may include training or attracting more skilled workers; tax policies that target virgin materials, rather than labour; quality assurance standards for professional repair services; and expanded Right to Repair legislation (Rogers, Deutz and Ramos, 2021).
- Develop and pilot complementary circular business models such as pay-per-use, rental, and second-hand to reduce environmental impact and offer affordable appliance service offerings; internalising the costs and benefits of designing appliances for repairability and longer product lifespans.

5.2. Limitations

5.2.1 Limited timeframes for monitoring behaviour change

Timeframes for monitoring baseline household behaviour and behaviour changes were limited to a three-month period for practical reasons. Ideally, a longer timeframe for observation would be employed to track and assess newly adopted behaviours. To mitigate, we will undertake a third final Behavioural Monitoring Survey assessment 6-months post study to see if the educational messaging has resulted in any long-term behavioural changes.

Short timeframes also meant meter reading results were limited. Because the targeted behaviour changes led to small, incremental savings in energy more time is needed for noticeable changes to energy use. Furthermore, changes to routine not related to educational messaging (i.e., visiting friends and family, participants away from home, changes in work schedules, etc.) impacted meter data. Meter installation was also limited to a select range of appliances due to physical barriers and energy load limits.

5.2.2 Household incomes were higher than average

Efforts in the recruitment process were made to include households with lower than average or average incomes. However, the households that met the criteria (i.e., appliance ownership, household make-up, employment, etc.) and were available to take part in the study only came from households with higher-than-average incomes. Access to households of various incomes would be necessary to gain a true understanding of the impact of the cost-of-living crisis on resource efficiency behaviours.

5.3 Future Research

Opportunities for further research include studies with extended timeframes and/or a wider range of participant income levels. Longer timeframes would allow researchers to measure the actual amount of energy and costs saved (per appliance) through energy-saving behaviours. A wider range of incomes would test the hypothesis that households with lower incomes may be more motivated by saving money and thus more willing to carry out resource efficiency behaviours. It has also been suggested that people with higher incomes are less likely to repair products themselves since they feel their time is more valuable (McCollough, 2007); further research is needed to understand how to develop the UK repair ecosystems to provide viable options for repair to all income levels.

To help develop more robust maintenance education the concrete effects of maintenance activities should be researched for various appliances. This can provide the motivational information consumers need to perform maintenance activities on their appliances, including the quantification of lifetime extension for properly maintained products. Additionally, studies focussed on the effects of consumer education for repair practices are lacking. This study was unable to test education on repair behaviour since this requires the presence of appliances in need of repair. Aside from education, other interventions such as design features, incentives, and training should be tested to see what enables consumers to choose to repair appliances more readily (Michie, Atkins and West, 2014).

Lastly, this study focused on a small sample set of 7 households for the purpose of gaining a deep understanding participant behaviours. While this type of research yields valuable data about consumer capabilities, opportunities and motivations, it could be interesting to extend the reach of the study to gain a broader societal perspective on resource-efficiency behaviours in the current economic climate.

6.0 Acknowledgments

This research was funded by the Association of Manufacturers of Domestic Appliances and the UKRI National Interdisciplinary Circular Economy Research Hub [EP/V029746/1].

This research would not be possible without research participants who opened their homes and lives up for observation to researchers from the University of Exeter. Thank you for your willingness and valuable contributions.

7.0 Bibliography

Ajzen, I. (1991) 'The theory of planned behavior', Organizational Behavior and Human Decision Processes, 50(2). Available at: https://doi.org/10.1016/0749-5978(91)90020-T

Alejandre, C., Akizu-Gardoki, O. and Lizundia, E. (2022) 'Optimum operational lifespan of household appliances considering manufacturing and use stage improvements via life cycle assessment', Sustainable Production and Consumption, 32. Available at: https://doi.org/10.1016/j.spc.2022.04.007.

Allcott, H. and Mullainathan, S. (2010) 'Behavioral Science and Energy Policy', Science, 327(5970).

AMDEA (2021a) Market Information. Available at: https://www.amdea.org.uk/industry-information/market-information/ (Accessed: 4 May 2023).

AMDEA (2021b) New Energy Labels. Available at: https://www.amdea.org.uk/campaigns/new-energy-labels/ (Accessed: 10 May 2023).

BEIS (2019) Energy efficiency: building towards net zero: Government Response to the Committee's TwentyFirst Report of Session 2017–19. Available at: https://publications.parliament.uk/pa/cm201919/cmselect/cmbeis/124/124.pdf (Accessed: 4 May 2023).

BEIS (2020) Energy Consumption in the UK (ECUK) 1970 to 2019. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020152/2020_Energy_Consumption_in_the_UK__ECUK_.pdf (Accessed: 4 May 2023).

BEIS (2023) Policy Paper: Energy Price Guarantee. Available at: https://www.gov.uk/government/publications/energy-bills-support/energy-bills-support-factsheet-8-september-2022 (Accessed: 4 May 2023).

Brette, O., Lazaric, N. and Vieira da Silva, V. (2017) 'Habit, Decision-Making, and Rationality: Comparing Thorstein Veblen and Early Herbert Simon', Journal of Economic Issues, 51(3). Available at: https://doi.org/10.1080/00213624.2017.1353866.

Brounen, D., Kok, N. and Quigley, J.M. (2013) 'Energy literacy, awareness, and conservation behavior of residential households', Energy Economics, 38. Available at: https://doi.org/10.1016/j.eneco.2013.02.008

Casado, F., Hidalgo, M.C. and García-Leiva, P. (2017) 'Energy efficiency in households: The effectiveness of different types of messages in advertising campaigns', Journal of Environmental Psychology, 53. Available at: https://doi.org/10.1016/j.jenvp.2017.08.003

Cooper, T. and Christer, K. (2010) 'Marketing Durability', in Longer Lasting Products: Alternatives to the Throwaway Society.

Cox, J. et al. (2013) 'Consumer understanding of product lifetimes', Resources, Conservation and Recycling, 79. Available at: https://doi.org/10.1016/j.resconrec.2013.05.003

Delmas, M.A., Fischlein, M. and Asensio, O.I. (2013) 'Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012', Energy Policy, 61. Available at: https://doi.org/10.1016/j.enpol.2013.05.109

DESNZ and BEIS (2021) Green Homes Grant: make energy improvements to your home (closed to new applicants). Available at: https://www.gov.uk/guidance/apply-for-the-green-homes-grant-scheme (Accessed: 4 May 2023).

DESNZ and BEIS (2023) Energy Trends and Prices statistical release: 30 March 2023. Available at: https://www.gov.uk/government/statistics/energy-trends-and-prices-statistical-release-30-march-2023#:~:text=Highlights%2520for%2520the%25203%2520month,basis%2520consumption%2520fell%2520-by%25207.0%2525 (Accessed: 4 May 2023).

DESNZ and OPSS (2021) Regulations: energy information. Available at: https://www.gov.uk/guidance/the-energy-labelling-of-products (Accessed: 4 May 2023).

Energy Savings Trust (2022) Top five energy consuming home appliances. Available at: https://energysavingtrust.org.uk/top-five-energy-consuming-home-appliances/ (Accessed: 10 May 2023).

European Commission (2021) About the energy label and ecodesign. Available at: https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/about_en (Accessed: 4 May 2023).

Galvin, R. and Sunikka-Blank, M. (2013) 'A Critical Appraisal of Germany's Thermal Retrofit Policy: Turning Down the Heat', Green Energy and Technology, 148. Available at: https://doi.org/10.1007/978-1-4471-5367-2.

Haines-Gadd, M. (2018) Emotional Durability Design Nine. Available at: https://eddnine.wixsite.com/framework (Accessed: 5 May 2023).

Haines-Gadd, M. et al. (2018) 'Emotional durability design Nine-A tool for product longevity', Sustainability (Switzerland), 10(6). Available at: https://doi.org/10.3390/su10061948.

Harari, D. et al. (2023) Rising cost of living in the UK. Available at: https://commonslibrary.parliament.uk/research-briefings/cbp-9428/ (Accessed: 4 May 2023).

Hardisty, D.J. and Weber, E.U. (2009) 'Discounting Future Green: Money Versus the Environment', Journal of Experimental Psychology: General, 138(3). Available at: https://doi.org/10.1037/a0016433.

Harmer, L. et al. (2019) 'Design, Dirt and Disposal: Influences on the maintenance of vacuum cleaners', Journal of Cleaner Production, 228. Available at: https://doi.org/10.1016/j.jclepro.2019.04.101

Hubbub (2020) The Fixing Factor: A Review of UK Attitudes Towards Repair and Sustainability. Available at: https://www.hubbub.org.uk/Handlers/Download.ashx?IDMF=5aa5d5ba-2c7c-4633-a441-7cb214d11e9f (Accessed: 5 May 2023).

Hueppe, C. et al. (2021) 'Investigating the real life energy consumption of refrigeration appliances in Germany: Are present policies sufficient?', Energy Policy, 155. Available at: https://doi.org/10.1016/j.enpol.2021.112275

Kirchherr, J., Reike, D. and Hekkert, M. (2017) 'Conceptualizing the circular economy: An analysis of 114 definitions', Resources, Conservation and Recycling, 127, pp. 221–232. Available at: https://doi.org/10.1016/J.RESCONREC.2017.09.005

Laitala, K. et al. (2021) 'Increasing repair of household appliances, mobile phones and clothing: Experiences from consumers and the repair industry', Journal of Cleaner Production, 282. Available at: https://doi.org/10.1016/j.jclepro.2020.125349

Lee, E. et al. (2020) 'From intention to action: Habits, feedback and optimizing energy consumption in South Korea', Energy Research and Social Science, 64. Available at: https://doi.org/10.1016/j.erss.2020.101430

legislation.gov.uk (2021) The Ecodesign for Energy-Related Products and Energy Information Regulations 2021. Available at: https://www.legislation.gov.uk/uksi/2021/745/contents/made (Accessed: 4 May 2023).

McCollough, J. (2007) 'The effect of income growth on the mix of purchases between disposable goods and reusable goods', International Journal of Consumer Studies, 31(3). Available at: https://doi.org/10.1111/j.1470-6431.2006.00504.x.

Michie, S., Atkins, L. and West, R. (2014) 'The behaviour change wheel', A guide to designing interventions. 1st ed. Great Britain: Silverback Publishing [Preprint].

Muranko, Ż. et al. (2020) 'Behaviour chains in circular consumption systems: the reuse of FMCGs', in Proceedings of the IS4CE2020 Conference of the International Society for the Circular Economy.

Ofgem (2021) Domestic Renewable Heat Incentive (Domestic RHI). Available at: https://www.ofgem.gov.uk/environmental-and-social-schemes/domestic-renewable-heat-incentive-domestic-rhi (Accessed: 4 May 2023).

ONS (2022a) Consumer price inflation, UK: December 2022. Available at: https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/consumerpriceinflation/december2022 (Accessed: 4 May 2023).

ONS (2022b) Energy prices and their effect on households. Available at: https://www.ons.gov.uk/economy/inflationandpriceindices/articles/energypricesandtheireffectonhouseholds/2022-02-01 (Accessed: 5 May 2023).

ONS (2023) What actions are people taking because of the rising cost of living?, Office for National Statistics. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/articles/whatactionsarepeopletakingbecauseoftherisingcostofliving/2022-08-05 (Accessed: 4 May 2023).

Ozaki, R. and Shaw, I. (2014) 'Entangled Practices: Governance, Sustainable Technologies, and Energy Consumption', Sociology, 48(3). Available at: https://doi.org/10.1177/0038038513500101

Pakula, C. and Stamminger, R. (2010) 'Electricity and water consumption for laundry washing by washing machine worldwide', Energy Efficiency, 3(4). Available at: https://doi.org/10.1007/s12053-009-9072-8.

Pozo Arcos, B. et al. (2021) 'Faults in consumer products are difficult to diagnose, and design is to blame: A user observation study', Journal of Cleaner Production, 319. Available at: https://doi.org/10.1016/j.jclepro.2021.128741.

Rahman, M.M., Rasul, M.G. and Khan, M.M.K. (2010) 'Energy conservation measures in an institutional building in sub-tropical climate in Australia', Applied Energy, 87(10). Available at: https://doi.org/10.1016/j.apenergy.2010.04.005.

Rogers, H.A., Deutz, P. and Ramos, T.B. (2021) 'Repairing the circular economy: Public perception and participant profile of the repair economy in Hull, UK', Resources, Conservation and Recycling, 168. Available at: https://doi.org/10.1016/j.resconrec.2021.105447.

Ruiz-Pastor, L. and Mesa, J.A. (2023) 'Proposing an integrated indicator to measure product repairability', Journal of Cleaner Production, 395. Available at: https://doi.org/10.1016/j.jclepro.2023.136434

Sabbaghi, M. et al. (2016) 'Business outcomes of product repairability: A survey-based study of consumer repair experiences', Resources, Conservation and Recycling, 109. Available at: https://doi.org/10.1016/j.resconrec.2016.02.014

Sniehotta, F.F., Scholz, U. and Schwarzer, R. (2005) 'Bridging the intention-behaviour gap: Planning, self-efficacy, and action control in the adoption and maintenance of physical exercise', Psychology and Health, 20(2). Available at: https://doi.org/10.1080/08870440512331317670.

Statista (2022) Producer Price Index (PPI): monthly output price of electrical equipment in the United Kingdom (UK) from January 2015 to March 2022. Available at: https://www-statista-com.uoelibrary.idm.oclc.org/statistics/285329/electrical-equipment-monthly-producer-price-index-ppi-in-the-uk/ (Accessed: 10 May 2023).

Statista (2023a) Consumer Market Insights. Household Appliances - United Kingdom. Available at: https://www-statista-com.uoelibrary.idm.oclc.org/outlook/cmo/household-appliances/united-kingdom (Accessed: 4 May 2023).

Statista (2023b) Electricity consumption in the United Kingdom (UK) from 1970 to 2021, by final user. Available at: https://www-statista-com.uoelibrary.idm.oclc.org/statistics/550592/uk-electricity-consumption-by-final-users/ (Accessed: 4 May 2023).

Stern, P.C. (2014) 'Individual and household behaviour in the domain of energy: Recent advances and remaining challenges', Energy Economics, 46, pp. 12–21. Available at: https://doi.org/10.1016/j.eneco.2014.06.017

Triandis, H.C. (1977) 'Cross-Cultural Social and Personality Psychology', Personality and Social Psychology Bulletin, 3(2). Available at: https://doi.org/10.1177/014616727700300202

Trotta, G. (2018) 'Factors affecting energy-saving behaviours and energy efficiency investments in British households', Energy Policy, 114. Available at: https://doi.org/10.1016/j.enpol.2017.12.042.

Turn2us (2020) Millions across the UK are living without household essentials. Available at: https://www.turn2us.org.uk/About-Us/Media-Centre/Press-releases-and-comments/Millions-across-the-UK-are-living-without-household (Accessed: 4 May 2023).

West, R. and Michie, S. (2020) 'A brief introduction to the COM-B Model of behaviour and the PRIME Theory of motivation', Qeios [Preprint]. Available at: https://doi.org/10.32388/ww04e6.2.

Zeeuw van der Laan, A. and Aurisicchio, M. (2019) 'Archetypical consumer roles in closing the loops of resource flows for Fast-Moving Consumer Goods', Journal of Cleaner Production, 236. Available at: https://doi.org/10.1016/j.jclepro.2019.06.306

Appendix 1: Change in Energy-efficient, Maintenance and Repair Behaviours on Household Electric Appliances

Behaviour	Question	Pre and post intervention		Appliance											
				Microwave	Oven	Hob	Airfryer	Slowcooker	Washing Machine	Tumble Dryer	Kettle	Fridge	Freezer	Toaster	Dishwasher
Energy Efficiency	To what extent do you agree or disagree, that you know how to improve the energy efficiency when using your appliances?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	1.6	2.571	2.286	2	2.25	3	3.2	3	2.429	2.667	2.833	3.25
			Standard Deviation	0.894	0.976	1.113	1	0.957	1.155	0.837	1.732	0.976	0.816	1.329	0.957
		POST	Number	5	7	7	2	4	7	4	7	7	6	6	5
			Mean	4.2	4.286	4.571	3	2.75	4.286	3.75	4.429	4.286	4.167	3.833	4.4
			Standard Deviation	0.447	0.488	0.535	0	1.258	1.113	1.258	0.787	0.756	0.753	1.472	0.548
	To what extent do you agree or disagree, there is an opportunity/ option for you to save energy when using your current appliances (e.g., appliance has eco-setting)?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	2.8	2.143	1.857	3.333	2.75	4	3.8	2.429	2	2.167	1.5	3.5
			Standard Deviation	1.643	0.9	0.378	0.577	1.258	1.414	1.095	1.618	0.816	0.753	0.548	1.291
		POST	Number	5	7	7	2	4	7	5	7	7	6	6	5
			Mean	2.8	3.286	3.143	3	2.5	4	3.6	3	3.286	3.167	2.667	3.4
			Standard Deviation	1.789	0.951	1.215	0	1	0.816	1.14	1.155	0.951	0.983	1.211	0.894
	How likely or unlikely would it be for you to always choose an option to save energy when using your appliances in the future?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	3.8	4.143	4	3.333	3.75	4.571	4.2	4.286	3.857	3.667	3.667	3.5
			Standard Deviation	0.837	0.9	0.816	0.577	0.957	0.535	0.447	0.756	1.069	1.033	0.816	1.732
		POST	Number	5	7	7	2	4	7	5	7	7	6	6	5
			Mean	3.8	3.867	4.143	3	3.5	4.429	4.4	4.286	3.857	3.833	3.167	4.4
			Standard Deviation	1.304	0.9	0.9	0	1	0.787	0.894	1.113	0.9	0.983	1.472	0.894

Behaviour	Question	Pre and post intervention		Appliance											
				Microwave	Oven	Hob	Airfryer	Slowcooker	Washing Machine	Tumble Dryer	Kettle	Fridge	Freezer	Toaster	Dishwasher
Maintenance	To what extent do you agree or disagree, that you know how to carry out maintenance activities to make your appliances last longer or prevent them from damage/breaking?	PRE	Number	5	7	6	3	4	7	5	7	7	6	6	4
			Mean	2.2	2.286	2.333	2	2.25	3.143	3.4	3.571	2.429	3	3.667	3.75
			Standard Deviation	1.095	0.951	1.366	1	0.957	1.215	0.894	1.618	1.272	1.265	1.506	1.258
		POST	Number	5	7	7	2	4	7	4	7	7	6	6	5
			Mean	3.4	3.857	4.286	2.5	3	3.714	3.25	4	3.714	3.5	4	3.4
			Standard Deviation	1.342	1.113	0.707	0	1.254	1.5	1.414	1.254	1.254	1.225	1.549	1.342
	To what extent do you agree or disagree, that there is an opportunity/ option for you to carry out maintenance activities on your current appliances to make them last longer or prevent them from damage/breaking?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	1.6	2.143	1.857	2.333	2	3.286	2.4	2.571	2.143	2.833	2.833	2.5
			Standard Deviation	0.894	1.464	1.215	1.155	1.155	1.704	1.517	1.512	1.464	1.472	1.602	1.291
		POST	Number	5	7	7	3	4	7	5	7	7	6	6	5
			Mean	4	3.571	3.857	2.333	2.5	4.714	4.6	4.714	4	4	3.5	4
			Standard Deviation	1.225	1.272	1.069	1.155	1	0.488	0.548	0.488	1	1.549	1.643	1.225
	How likely or unlikely would it be for you to maintain your appliances in the future to make them last longer or prevent them from damage/ breaking?	PRE	Number	5	7	7	3	4	7	5	7	6	6	6	4
			Mean	3.8	4.286	4.286	4	3.5	4.571	4.6	4	4.167	4.167	4.167	4.5
			Standard Deviation	1.643	1.113	1.113	1	1	0.535	0.548	1.414	1.169	1.169	1.602	0.577
		POST	Number	5	6	6	2	4	7	5	7	7	6	6	5
			Mean	4.2	4	4.714	3	3.5	4.571	4.4	4.143	3.857	3.667	3.833	4.4
			Standard Deviation	1.304	1	0.488	0	1	0.535	0.548	1.069	1.069	1.033	1.472	0.548

Behaviour	Question	Pre and post intervention		Appliance											
				Microwave	Oven	Hob	Airfryer	Slowcooker	Washing Machine	Tumble Dryer	Kettle	Fridge	Freezer	Toaster	Dishwasher
Repair	To what extent do you agree or disagree, that you know what to do to repair your appliances if they break?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	1.6	1.429	1.714	2.333	2	2	1.6	1.714	1.714	1.667	2.5	1.25
			Standard Deviation	0.894	0.787	0.951	1.155	1.155	1.155	0.894	0.951	1.113	0.816	1.517	0.5
		POST	Number	5	7	7	3	4	7	5	7	7	6	6	5
			Mean	1.6	1.857	2.143	3	2.5	1.857	1.4	2	1.857	2	3	1.8
			Standard Deviation	0.548	0.69	1.069	0	1	1.464	0.548	1.155	0.9	0.894	1.549	0.837
	To what extent do you agree or disagree, that there is an opportunity/ option for you to repair your current appliances if they break?	PRE	Number	6	7	6	3	4	7	5	6	6	6	6	4
			Mean	1.667	2.857	2.5	2.333	2	3	2.8	2.5	3	3.167	2.833	2.5
			Standard Deviation	1.211	1.464	1.643	1.155	1.155	1.633	1.643	1.643	1.549	1.329	1.722	1.732
		POST	Number	5	7	7	2	4	7	5	7	7	6	6	5
			Mean	2	2.143	2.143	3	2.5	2.571	2.2	2.429	2.286	2.167	3.5	2
			Standard Deviation	1.225	1.069	1.069	0	1	1.512	1.643	1.618	1.113	1.169	1.517	1.414
	How likely or unlikely would it be for you to repair your appliances in the future when they break?	PRE	Number	5	7	7	3	4	7	5	7	7	6	6	4
			Mean	2.6	3.429	3.571	3.667	3.5	3.714	3.6	3.286	3.429	3.333	3.833	3.5
			Standard Deviation	1.817	1.397	1.512	0.577	0.577	0.951	1.517	1.604	1.397	1.506	1.472	1.732
		POST	Number	5	7	7	2	4	7	5	7	7	6	6	5
			Mean	2.8	3.143	3.286	3	3	3.143	2.4	3	3.286	3.167	3.5	2.8
			Standard Deviation	1.789	1.345	1.704	0	0	1.574	1.673	1.732	1.38	1.472	1.517	1.789

Appendix 2: Intention and Actual Performance of Consumer Educational Messages

Appliance	Behaviour	Intention on (mean)	Intention on (SD)	Action (mean)	Action (SD)	No. of times performed
Washing Machine	How likely are you to consider using the low temperature setting when laundering in the future?	4.4 2.9	1.1 34	4	1.4 14	
	How likely are you to load your washing machine at an optimal full load in the future?	4.2 86	0.7 56	4.4 29	0.7 87	
	How likely are you to consider the size of laundry load when using your washing machine in the future?	4.4 29	0.7 87	4.4 29	0.7 87	
	How likely are you to clean your washing machine in the future?	4.2 86	1.1 13	4	4.1 59	0-10
	Based on the information above, how likely are you to use eco-setting on your washing machine in the future?	3.7 14	0.4 4	3	1.9 15	
Kettle	How likely are you to boil only the amount of water you need when using your kettle in the future?	4.2 86	1.1 13	4	1	
	If you have / had a temperature setting available on your kettle, how likely would you choose to boil water to a lower temperature in the future?	4.2 86	1.1 13	1.4 29	1.1 34	
	How likely are you to descale your kettle in the future?	4.4 29	0.5 35	0.1 43	0.3 78	0-1
Fridge	How likely are you to keep your fridge full in the future?	2.8 57	1.2 15	3.2 86	0.9 51	
	How likely are you to use a power saving setting in the future?	3.4 29	1.1 34	1	0	
	How likely are you to adjust the temperature dials in your fridge in the future?	3.5 71	1.1 34	0.1 43	0.3 78	0-1
	How likely are you to check the actual temperature in your fridge in the future (using a thermometer)?	2.2 86	0.9 51	0.1 43	0.3 78	0-1
	How likely are you to clean your fridge coils in the future?	1.5 71	1.1 34	0.1 43	0.3 78	
	How likely are you to clean your fridge door seals in the future?	3.8 57	1.0 69	0.2 86	0.4 88	1
	How likely are you to inspect your fridge door seals in the future for cracks or splits?	4.2 86	0.4 88	0.4 29	0.5 35	1
	How likely are you to replace your fridge door seals in the future if there are cracks or splits?	3.4 29	1.1 34	0	0	0

Appliance	Behaviour	Intention on (mean)	Intention on (SD)	Action (mean)	Action (SD)	No. of times performed
Freezer	How likely are you to ensure you avoid opening the freezer door too frequently or for too long in the future?	4.3 33	1.2 11	4.1 43	1.5 74	
	How likely are you to defrost your freezer at least once a year in the future?	3.1 67	1.4 72	0	0	0
	How likely are you to check if your freezer has auto-defrost function in the future?	4.1 67	1.3 29	0.1 43	0.3 78	0-1
	How likely are you to engage the auto-de-frost function (if available) in the future?	4.3 33	1.2 11	0	0	0
	How likely are you to consider keeping your freezer full in the future?	4.6 67	0.5 16	4	1.4 14	
Oven	How likely are you to avoid preheating in the future?	3.3 33	1.2 11	3.1 43	1.0 69	
	How likely are you to cook several dishes at the same time in your oven in the future?	3.5	1.6 43	2.1 43	1.4 64	
	How likely are you to avoid opening the oven door during cooking in the future?	3.5	1.3 78	3.5 71	0.7 87	
	How likely are you to turn the oven temperature to zero towards the end of cooking time to use some 'free' heat in the future?	3.3 33	1.0 33	2.1 43	1.4 64	
	How likely are you to remove unnecessary accessories from your oven in the future?	4.8 33	0.4 08	3.7 14	1.6 04	
	How likely are you to clean your oven's interior every three months in the future?	3.6 67	1.3 66	0.5 71	0.7 87	0-2
Hob	How likely are you to cook on the ring closest in size to the bottom of your pan in the future?	4.4 29	0.5 35	4.8 57	0.3 78	
	Based also on the information above, how likely are you to use steamer to cook multiple foods at the same time using a single ring in the future?	2.8 57	1.3 45	1.5 71	1.1 34	
	Based also on the information above, how likely are you to use pans that match the size of your meal in the future?	4.8 57	0.3 78	4.4 29	0.5 35	
	Based also on the information above, how likely are you to keep the lid on pans when cooking on the hob in the future?	4	1.4 14	3	1.5 28	
	Based on this information, how likely are you to clean your hob regularly in the future?	4.7 14	0.4 88	7.1 43	3.7 61	1-10
	Based on this information, how likely are you to use your microwave instead of the oven in the future?	4	1.2 25	1.2 86	1.4 96	0-4

Appliance	Behaviour	Intention on (mean)	Intention on (SD)	Action (mean)	Action (SD)	No. of times performed
Microwave	Based also on the information above, how likely are you to batch cook meals and reheat using the microwave in the future?	4.4	0.548	3.2	0.837	
	Based on this information, how likely are you to clean your microwave regularly in the future?	4	1.225	1.286	1.496	0-4
	Based on this information, how likely are you to cover your food when cooking using your microwave in the future?	5	0	4.8	0.447	
	Based on this information, how likely are you to avoid running the microwave empty in the future?	5	0	5	0	
	Based on this information, how likely are you to use the eco-setting in the future?	4.667	0.516	4.2	1.789	
Dishwasher	Based also on the information above, how likely are you to run your dishwasher during off-peak times in the future?	4	0.894	3.6	1.673	
	Based on this information, how likely are you to use your dishwasher instead of hand-washing your dishes in the future?	4.167	0.983	4	1	
	Based on this information, how likely are you to run a full dishwasher in the future?	5	0	4.8	0.447	
	Based on this information, how likely are you to clean the dishwasher filter once a month in the future?	3.167	0.983	0.429	0.787	0-2
	Based also on the information above, how likely are you to clean the dishwasher interior once a month in the future?	3.333	0.816	0.714	1.496	0-4
	Based on this information, how likely are you to load your dryer drum 3/4 full in the future?	4.4	0.548	3.8	0.837	
Dryer	Based also on the information above, how likely are you to use your tumble dryer less often in the future?	3.8	1.095			
	Based also on the information above, how likely are you to choose to hang dry your laundry more often in the future?	3.8	1.643	4	0.707	
	Based on this information, how likely are you to select a moisture sensing setting when using your tumble dryer in the future?	4.4	1.342	2.8	2.049	
	Based on this information, how likely are you to use washing machine quick spin cycle to drain excess water from your laundry in the future?	4.6	0.548	3.2	1.789	
	Based on this information, how likely are you to clean the lint filter and filter housing every 4-5 cycles in the future?	3.6	1.517	1.571	2.149	0-5
	Based on this information, how likely are you to clean the filter drawer/condenser every 4-5 cycles in the future?	3.4	0.894	1	1.528	0-4

Appendix 3: Summary Consumer Educational Messages

How to Save Energy, Resources, and Extend the Life of Your Appliances

DAY 1 WASHING MACHINES

1. Washing clothes at a lower temperature can help you reduce how much energy you use and save you as much as £40 a year. Modern washing machines can clean clothes effectively at lower temperatures such as 30°C degrees. Changing your settings from 40°C to 30°C means you could get 3 cycles instead of 2 using the same amount of energy.
Source: Gov.uk

2. Washing at an optimal full load of laundry can save money on energy, water, detergent, and can help your washing machine last longer. Check your washing machine manual to see how full you should fill your drum. As a rule of thumb, for an optimal full load leave a hands-width gap at the top of the washing machine drum when loading. This roughly equates to filling 3/4 of the drum.
Source: Bosch, Beko

3. Choosing the right load size can help your washing machine to last for longer. Overloading increases the pressure within the drum, especially when it is spinning at a high speed - it can potentially cause damage to the drum bearings and even cause the glass door to shatter. Underloading the machine greatly reduces the efficiency of a cycle. If you have a newer model, your washing machine may be able to detect load size automatically (by weight); check your instruction manual to see if yours has this technology. If you regularly wash a half-load of laundry, select a 'small load' setting on your machine if you have one, or use the weight detection option; this could save you £57 over the year on energy and water.
Source: AMDEA, Bosch, Beko

4. Keeping your washing machine clean will help it run efficiently, extend its lifespan, and make sure that no bacteria has the chance to grow.

Clean the drum and drainage pipes by running the hottest cycle or use a drum clean programme on your machine with a cup of vinegar, or a cleaning product of choice, every 1-3 months.

Wipe down the rubber seal around the door with vinegar or a bleach solution to prevent mold and build-up to help maintain the seal and keep your machine fresh and clean.

Rinse the detergent drawer to remove the build up of residue detergent. You can remove the drawer by lifting it slightly as you pull it all the way out.

Clean the pump filter every 3 to 4 months. This is what stops things like buttons and coins getting stuck in the drainage pipe. You'll find it behind a cover at the bottom corner of the appliance.
Source: Beko

DAY 2 ELECTRIC KETTLES

1. By boiling your kettle for a shorter time you can save energy and money with each use. Kettles use a constant flow of energy throughout a boiling cycle so the key to reducing energy is to boil the water for a shorter time. Boiling only the amount you need will take less time than boiling a full kettle. Measure out your water in the kettle first before boiling. By not overfilling your kettle, you can save £13 a year.

Also, if your kettle has multiple temperature settings, choosing a lower temperature can reduce the amount of time your kettle is on for. In some cases, such as when making certain beverages, you don't need the water to reach 100 degrees. For brewing types of green tea you need 65 to 85 degrees water, and for black tea between 90 and 100. That small temperature difference can save you energy.
Source: Phillips, Energy Saving Trust, Dualit

2. Over time, lime builds up inside your kettle. You can descale it. Descaling your kettle regularly, especially if you live in a hard water area, can help reduce energy. A kettle full of limescale will take longer and use more energy to boil the same amount of water as one that is descaled. To descale your kettle, fill it with water up to the MAX level and boil. Add two cups of white vinegar into the boiled water. Keep the solution in the kettle for a few hours, or overnight. Then pour it out and rinse the inside thoroughly. Fill the kettle with clean water and boil it. Empty the kettle and rinse it with water again. You can repeat these steps if there's still some lime build up. You can also use a commercial kettle descaler - make sure you follow the instructions on the package.
Source: AMDEA, Phillips, Beko

DAY 3 FRIDGES

1. Keep your fridge full. When a fridge contains more items, there is less air to keep cool so it doesn't have to work as hard. When sufficiently loaded, items help keep each other cool. You should be able to keep your refrigerator at least 2/3 full. If your fridge is too big, add jugs of water in both compartments. That said, don't go cramming it full to bursting—good airflow is important for efficient refrigerator operation. Also, watch out for air vents and make sure items are not blocking them.
Source: Beko

2. Use power saving settings. While not a feature on all refrigerators, if your appliance has a power saver mode or vacation mode, put it to use! If there's not very much in your fridge to keep cool, then engaging the power saver mode will reduce energy consumption.
Source: Beko

3. Check the temperature of your refrigerator with a thermometer. A refrigerator set 5 degrees colder can use as much as 25% more energy with no additional functional benefit. The ideal fridge temperature is between 3°C and 5°C. But before you touch those dials, just be aware that it takes 24 hours for your fridge to adjust to any changes you make.

Keep an eye on the actual temperature inside your refrigerator. The temperature you set your fridge to isn't necessarily the temperature you're actually getting. Your refrigerator might be slightly warmer or slightly cooler that the temperature set on the dial. To check the optimum temperature, leave a thermometer in a glass of water and place it in the fridge overnight. Check the temperature on the thermometer the first time you open the door next day. A water temperature somewhere between 2.2°C and 3.3°C is ideal. If your thermometer is telling you you're at the lower end of this range, you could nudge your appliance's temperature dial up a little. This will translate to noticeable energy savings.
Source: Beko, Currys

4. Keep the coils of your fridge clean. The condenser coils on the back of your refrigerator are crucial in keeping the temperature inside cool. However, over time they can collect a serious amount of dust if left unchecked.

Keeping the condenser coils clean will reduce how hard your fridge needs to work each time it needs to get the temperature back to the set level. This will ultimately extend the life of your refrigerator. Just remember, it's best to unplug the appliance when cleaning the coils, and a vacuum or brush is the best tool for the job. This should be done once every 6 months on average.
Source: Beko

5. Check and clean door seals. The seals around your refrigerator's door are the barrier between the cool air inside and the warm air outside. Any break in this seal will mean warm air gets into the refrigerator, so it'll have to work harder to maintain the set temperature. Keep the door seals clean and have them replaced if you notice any cracks or splits.
Source: Beko

DAY 4 FREEZERS

1. Only open the door for as short a time and as infrequently as possible.
Your freezer needs to keep the air inside the freezer at a certain temperature to be able to keep food frozen. If the freezer door is opened too frequently or is kept open for long periods, warm air entering the freezer will increase the air temperature inside.
Source: Beko

2. Keep your freezer full. Similar to your fridge, a fuller freezer has less air to keep cool, so doesn't have to work quite as hard as a sparsely populated appliance. When sufficiently loaded, items help keep each other cool. You should be able to keep your freezer at least 2/3 full. If your freezer is not very full, add bottles of water to each section. That said, don't go cramming it full to bursting - good airflow is important for efficient freezer operation. Also, watch out for air vents and make sure items are not blocking them.
Source: Beko

3. Keep your freezer compartment clean and defrosted.

Any ice, especially ice over a ¼ inch thick, will act as insulation to the rest of the freezer compartment. This means that your freezer will be working extra hard to keep all of your food below freezing. Some freezers have an auto-defrost function, but older models will need to be defrosted once a year, or if there is more than ¼ inch of ice build-up.
Source: Whirlpool

DAY 5 OVENS

1. Slightly change your cooking routine to lower your energy bill.

- Avoid preheating the oven and save 20% on energy usage. Most dishes, like roasts and casseroles can be placed in the cold oven (especially a fan-assisted one).

- If you can, use your oven to cook several dishes at the same time - this can save up as much as 45% of the energy, so load your dishes side-by-side.

- Avoid opening the oven door during cooking, and instead checking the food through the glass door. This can save you as much as 25% in energy, that otherwise can be lost.

- Use residual oven heat and save as much as 10% of the energy when cooking. For example, for a roast with one hour cooking time, turn the oven temperature to zero after 50 minutes and use that 10 minutes of 'free' heat.
Source: AMDEA

2. Take any accessories that aren't used (trays, grids, baking dishes) out of your oven when cooking. This can save you as much as 20% of the energy used every time you use your oven, because the unnecessary accessories won't need heating up in order for the oven to reach the set temperature.
Source: AMDEA, Whirlpool

3. Schedule a routine cleaning of your oven's interior at least once a month.

Clean your oven every three months. It's not the most glamorous of tasks, but cleaning your oven is a must. Improving fire safety, increasing efficiency, reducing risk of contamination and prolonging the life of your appliance, are just a few perks to cleaning your oven regularly.

- **Fire safety.** Lack of regular cleaning can increase fire risk. That's right, the buildup of grime means there's a higher chance of fire. Burning food debris can also create fumes and smoke

- **Energy efficiency.** A clean oven is also more efficient. Better heat distribution means lower energy usage, a quicker warm-up time and even bakes

- **Food hygiene.** Grime buildup can cause bacteria contamination and even change the taste of your food. Cleaning the oven is an easy way to minimise this risk

- **Longevity.** Dirty ovens tend to wear out much more quickly; they're made to work harder and use more energy. Some mechanisms can even become blocked and stop working. Cleaning is a must to make your appliance last
Source: Energy Savings Trust

DAY 6 HOB

1. Consider your cooking technique when using the hob.

- Pick the right pot for the hob. Choose the ring that's closest in size to your pot or pan's bottom to minimise energy use and avoid wasting heat.

- Use a steamer with the pot to cook different things at the same time using the same ring.

- Use smaller pans. The smaller your pan, the less heat you'll need. Using the right size pan for your meal means less energy wasted.

- Keep saucepan lids on and your food will heat up faster. Cooking with a lid on can save as much as 25% on energy usage. Glass lids are recommended so you can supervise without having to lift the lid and letting heat escape.
Source: British Gas, EDF, Iceland

2. It's good practice to clean your hob thoroughly after every use. Not only is this a great way of preventing spillages from being burnt into or dried up on the hob surface, and difficult to clean, but also this will help to keep your hob looking its best.
Source: Beko

3. Watch the video below to see how to clean your induction hob or gas hob.

https://youtu.be/9bms0Khdx74
Source: Beko

DAY 7 MICROWAVE

1. Using microwaves is a more energy efficient way of cooking than ovens. Microwaves are incredibly energy-efficient appliances. By heating the food directly, rather than heating the air around it, less energy is wasted, and cooking times are shortened dramatically. Because of this, cooking food in a microwave rather than a standard oven can save significant amounts of energy. For example, it costs just 4p to cook a baked potato in the microwave compared to £1.04 in the oven.

Try and utilise your microwave as much as possible. Microwaves are perfect for steaming vegetables, cooking scrambled eggs, and making porridge for a quick breakfast. Equally, microwaves are great for defrostingand reheating batch cooked meals. Making large meals ahead of time and reheating small portions throughout the week will help to reduce your utility bills as you are only heating the oven once to cook a large quantity of food.
Source: AMDEA, Beko

2. Watch the video below for information on how cleaning your microwave helps to prolong its lifespan.

https://youtu.be/VPCsnn7b6Vo
Source: AEG

DAY 8 DISHWASHERS

1. Use the ECO setting. Using the ECO setting on your dishwasher will reduce energy and water consumption by 25-30%. These take longer and are only really worthwhile on full loads.

If the program takes longer, how can it be more economical? Good question. The answer is actually quite simple - with a longer wash-time, the machine doesn't have to heat up the water as much to achieve the same result as a shorter wash. This allows the appliance to use less energy when compared to the auto program, for example.
Source: Bosch, Beko

2. Take advantage of off-peak energy tariffs. Many energy tariffs offer cheaper electricity at certain times of the day, typically during off-peak hours, so be mindful of when you run your dishwasher. This is much easier if your appliance has a delayed-start or timer function you can use to set your dishwasher to wash during off-peak times (rates vary by supplier, check with your energy provider).
Source: Beko

3. Use a dishwasher instead of washing by hand, but make sure to run it when it's full. You could save up to £46 per year on your water bill by using your dishwasher over a hand-wash. A typical dishwasher uses about 15 litres of water when washing up 15 place settings, whereas washing by hand can use as much as 126 litres of water (over 8 times more!).
Source: AMDEA

4. Run your dishwasher when it's full. Wait until your dishwasher is full before you run a cycle. A half empty appliance uses the same amount of energy, water and detergent to clean fewer dishes, so it's obviously not the most efficient way to do things. Remember though, proper loading of your dishwasher is important in terms of cleaning efficiency, so be careful not to overload the appliance.
Source: Beko

5. Clean your dishwasher monthly. It is a good idea to clean your dishwasher regularly - this will prevent costly repairs, keep it running smoothly and leave your dishes sparkling clean. If you're getting residue on your dishes after a wash, a clogged filter could be the problem so make sure you regularly wash it – its job is to stop leftover food getting into the pump. Take out the bottom tray and lift the cylindrical filter out then simply wash it in warm water. Cleaning that filter protects the pump, which could save you £100 or more for the supply and fit of a new one.

You can also use white vinegar to clean your dishwasher interior, door seals and draining pipes. Running a cleaning cycle in your dishwasher with distilled white vinegar can neutralize odors and clean soap scum. Add two cups of white vinegar into a dishwasher safe bowl onto the bottom rack of the empty dishwasher and run a normal wash cycle. Let the machine air dry at the end of the cycle.

You can also use a commercial dishwasher cleaner - check on-packaging instructions before use.
Source: Whirlpool, iFixit

DAY 9 – TUMBLE DRYERS

1. Use your tumble dryer less frequently, always at full load - around 3/4 of a drum. Tumble dryers are one of the most energy-intensive devices in the home. Using your tumble dryer less could save you £70 a year.

Putting the right amount of laundry (around 3/4 of a drum) in your tumble dryer is key to getting the best performance out of the appliance. If you overload it, you can hinder drying performance and can even cause damage to the machine. If you underload it, you'll be using a full programme's worth of energy just to dry a few items.

That said, the best way to save energy drying your clothes is to hang dry them outside, or inside with proper ventilation.
Source: Gov.UK, AMDEA, Beko

2. If your tumble dryer has a feature that detects moisture levels, use this feature instead of timed programmes. Most modern tumble dryers have sensors that will finish the program automatically when they detect that the clothes inside are dry. Timed programmes will continue to run, even if the laundry in the drum is dry, and that's clearly a waste of energy.
Source: Beko, Which

3. Use your washing machine's spin cycle to remove excess water. Selecting an additional quick spin cycle on your washing machine after your laundry is done - and before tumble drying - will drain more excess water from your clothes. Washing machine spin cycles cost less to run than tumble drying, and the dryer will then need to run for less time to dry your clothes.
Source: Beko, Which

4. Keeping the lint and evaporator filters clean is essential both for drying performance and general care of your tumble dryer. Blocked filters make the motor work harder and increase energy consumption. Appliance user manuals, and manufacturers, recommend cleaning the lint filter after every drying cycle. Regularly (once every four or five cycles) deep clean by washing the lint filter under the tap and using a vacuum cleaner on a low suction setting to clean out the lint filter housing (the actual lint trap component). Make sure that the lint filter is completely dry before you put it back in the housing.
Source: Beko

5. It's not just the lint filter you have to keep clean, there's the filter drawer or condenser too. Heat pump tumble dryers have a filter drawer, whereas condenser models have a condenser to do the same job. You can find both behind the kick plate cover at the bottom corner of the tumble dryer. Open the cover and remove the filter from its housing.

Every appliance is different, so check your user manual if you're not sure how to do this. The filter drawer itself can be opened up to expose the foam pad inside. Clean the surfaces of the filter housing either by hand or with a vacuum cleaner set to a low suction power. If the foam pad looks dirty, you can give this a rinse under the sink. Make sure you let the pad dry before putting it back in the housing and back in the tumble dryer. Aim to do this once every four or five cycles.

CE-HUB

UKRI National Interdisciplinary Circular Economy Research

AMDEA

The Association of Manufacturers of Domestic Appliances

University of Exeter Business School

2023BS007