Potential impact of UK Repair Cafés on the mitigation of greenhouse gas emissions

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Abstract

The repair of household products at Repair Cafés has risen in popularity within the UK over the last few years, increasing the potential for community repair to contribute towards the development of a circular economy in terms of reductions in material flows and greenhouse gas (GHG) emissions. This research aims to better understand and quantify the potential of UK Repair Cafés to mitigate GHG emissions, by looking at the combined data from 2838 attempted repairs from 13 Repair Cafés. The data analysis develops a profile of the most common products taken for repair, repair success rates and associated spare parts usage. Product specific embodied GHG data from LCA studies and EcoAudit 2017, is used to determine the potential for displacement of GHG emissions embodied within new replacement products, as a result of successful repairing faulty products at Repair Cafés. Further questionnaire-based data from visitors and volunteers is combined to help build a broader picture of transportation related GHG emissions, and product owner behavior post repair to account for the effect of repair related direct and indirect GHG emissions.

Results show that Repair Cafés provide a net GHG environmental benefit, with an average of -24 kgCO_2e saved per completed repair via the displacement of new product purchases in 88% of repair cases. Repair rates average 67% with clothing and textiles having the highest success rate at 89%. GHG emissions from increased consumption due to the rebound effect account for the highest offset to repair GHG emission savings at 4.4 kgCO_2e per repair. Over 50% of product repairs are successfully completed using no spare parts, with spare parts accounting for average GHG emissions of just 0.2 kgCO_2e per repair across all repairs.

Repair Cafés therefore offer an effective repair service to local communities and wider benefit to the environment in terms of reducing raw material consumption and the mitigation of greenhouse gas emissions.

Acknowledgements

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List of Abbreviations

Term or symbol	Meaning
AV	Audio and video
CE	Circular economy
CO_2e	Carbon dioxide equivalent
Df	Displacement factor for new product purchases all products (successfully repaired)
Et	Life expectancy of new product replacement (yrs)
GHGs	Green House Gases ($kgCO_2e$)
GWP	Global Warming Potential
kg	Unit of mass - kilograms
Lf	Landfill GHG emissions ($kgCO_2e$) displaced by waste prevention
Ne	Embodied GHGs ($kgCO_2e$) for new replacement product
NGO	Non-governmental organization
ns	Number of completed product repairs for all attempted repairs
nt	Number of attempted repairs (or products taken for repair)
Pb	Probability of owner not buying a new product (0-1)
Pe	Embodied GHG emissions ($kgCO_2e$/kg) for product type
Pm	Repaired product's mass (kg)
Pn	Total sum of potential mitigated GHG emissions ($kgCO_2e$)
Ps	Perceived £ saved following visit to a Repair Café
Rb	Rebound GHG emissions ($kgCO_2e$) as a result of consumption of goods/services
Rd	Return journey distance (km)
Re	Repair related GHG emissions ($kgCO_2e$)
Rl	Repaired product's life extension period as a fraction of its original design life
Sc	Service or goods consumed ($kgCO_2e$/£)

Sp	Embodied GHG emissions ($kgCO_2e$) for spare parts used
Tf	Repaired product use time before failure (yrs)
Tp	Transportation tailpipe CO_2 emissions ($kgCO_2$) for journey distance
Vc	Vehicle category CO_2 emissions (grams CO_2/km)
Ve	Embodied GHG emissions ($kgCO_2e$) for vehicle proportioned to journey distance
Vl	Vehicle life expectancy (kms)
Vm	Average vehicle mass (kg) for vehicle category
WEEE	Waste electrical and electronic equipment

1 Introduction

This section outlines the problem and sets out the aims and research questions. The final part of this chapter is an overview of the dissertation structure.

1.1 Problem outline

Repair Cafés are community volunteer run events held in villages, towns and cities, that offer the opportunity for owners of broken and faulty household products to have them repaired by 'expert' volunteers at little or no cost. Many Repair Cafés have been initiated as grassroots projects by individuals, groups and organizations working towards greater self-sufficiency and reduction in their environmental impact (Charter and Keiller, 2014). As the Repair Café movement has grown[1] and become more organized, the need to share data, monitor progress and report information to the public and decision makers has become more important. One key environmental indicator is the mitigation of greenhouse gas emissions (GHGs) that are a key driver of climatic change, and often cited by Repair Cafés in the media and by other repair organisations (Lyons, 2018). However, figures quoted often use different calculation methods and omit potential sources of GHG emissions associated with repair activities[2].

By virtue of their nature, UK Repair Cafés attempt to repair a very wide range of household products, transported over a range of distances, using an assortment of spare parts resulting in a range of repair outcomes. The problem of reporting is therefore complex for volunteer-based Repair Cafés to meaningfully assess and quantify the effect their repair activities have on GHG emissions, without relevant and accessible data and a standardized methodology.

1.2 Aim and research questions

The aim is to develop a methodology and data collection approach that could be used to answer the key research question: *Do Repair Café activities help mitigate greenhouse gas emissions and if so what order are these likely to be?*

As indicated above, the ability to actively report progress is seen to be important within the repair community. A secondary aim is therefore to produce data in the form of product specific information about embodied GHG emissions that could be used and applied by individual

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[1] Since the formation of the Repair Café Foundation (2009) the number of Repair Cafes in the UK has grown to 52. See: https://repaircafe.org/en/visit/

[2] Restart Project calculation method: https://therestartproject.org/hrf_faq/how-are-the-figures-calculated/ Repair Café Foundation 1kgCO_2e/kg of product, see: https://repaircafe.org/en/200000kg-of-co2-emissions-saved/

Repair Cafés to monitor and report their performance in the mitigation of GHG emissions. These figures could also act as a baseline from which to assess future performance.

A number of further research questions arise as a result of trying to answer the main research question:

- What are the main types of household products presented for repair at UK Repair Cafés?
- How successful are 'expert' volunteers at repairing each of the product types seen?
- What are the type of product failures reported and spare parts needed?
- How effective are repairs at displacing new product purchases and waste going to landfill?
- How far do visitors travel to and from Repair Cafés, and the level of GHG emissions associated with the different modes of transportation used?
- How long do repaired products need to work post repair to start providing a net reduction in GHG emissions?
- Do other forms of consumption and therefore GHG emissions result from the provision of a 'near free' repair service?

1.3 Dissertation structure

The dissertation is presented in a number of sections: This section gives an outline of the problem being approached and the specific research questions being addressed.

Section 2: Provides a descriptive background of sustainability, increasing concerns over product waste and the need to monitor and reduce greenhouse gas emissions. The recent rise in popularity of Repair Cafés is considered within the UK and how they can help tackle wider sustainability and environmental issues within society.

Section 3: Reviews the academic literature to look more specifically at the underlying issues of product consumption and GHG emissions driving climate change. The concept of a circular economy and how repair can potentially contribute to slowing consumption and reducing GHG emissions is reviewed. Existing field research is also considered to help frame this research within the context of previous academic work.

Section 4: Describes the underlying methodology used to collect and analyze data to produce the quantitative outputs needed to determine how effective Repair Cafés are at mitigating GHG emissions.

Section 5: Presents the results of the data analysis in a step by step approach aligned with the proposed methodology. Non-related GHG emissions findings from the data are also presented where they might be relevant for consideration within future sustainability strategy.

Section 6: Discusses the results of the findings to examine their practical significance, together with overall conclusions and recommendations for possible future research.

2 Background

2.1 Economy and a sustainable future

Today's economic system is still largely a linear one relying on continuous consumption (Jackson, 2009; Seyfang, 2009). Consumerism has become the dominant social paradigm and driver of the world's sustainability problems (Halliday, 2002). Materials are extracted, processed and manufactured into products, used for ever shorter life-cycle periods and then discarded from the economy as waste (Gmelin et al., 2014).

"The linear economy is driven by 'bigger-better-faster-safer' syndrome, in other words, fashion, emotion and progress. It is efficient at overcoming scarcity, but profligate at using resources in often-saturated markets." (Stahel, 2016, p.436)

This linear process in not sustainable since the Earth's resources are finite, and physical materials and processes within the economy operate within the First[3] and Second Law of Thermodynamics, the entropy law (Daly and Farley, 2011). Central to Daly and Farley's argument is that modern economic thinking and practice fails to consider that the Earth is a closed system with respect to its resources and biosphere. The human economy operates within this closed system taking in high entropy (useful) resources and emitting low entropic (less useful) waste. If the size and throughput of the economy becomes too large the remaining carrying capacity of the biosphere is less able to absorb and recycle waste materials (Figure 2.1). Daly (2007, 2015) argues that we already live in a 'full world' as entropic input has become too large, and part of the problem is with our economic construct; in that we do not value nature in the same way as labour and capital. Where little labour and capital is

[3] Law of the conservation of energy, energy (and matter) cannot be created or destroyed. However, it does change its form from useful to less useful energy, 'heat' that increases disorder. See https://www.britannica.com/science/thermodynamics

required to transform natural resources into products (high natural capital compared to human capital deployed) 'the lower the price we place upon it.'

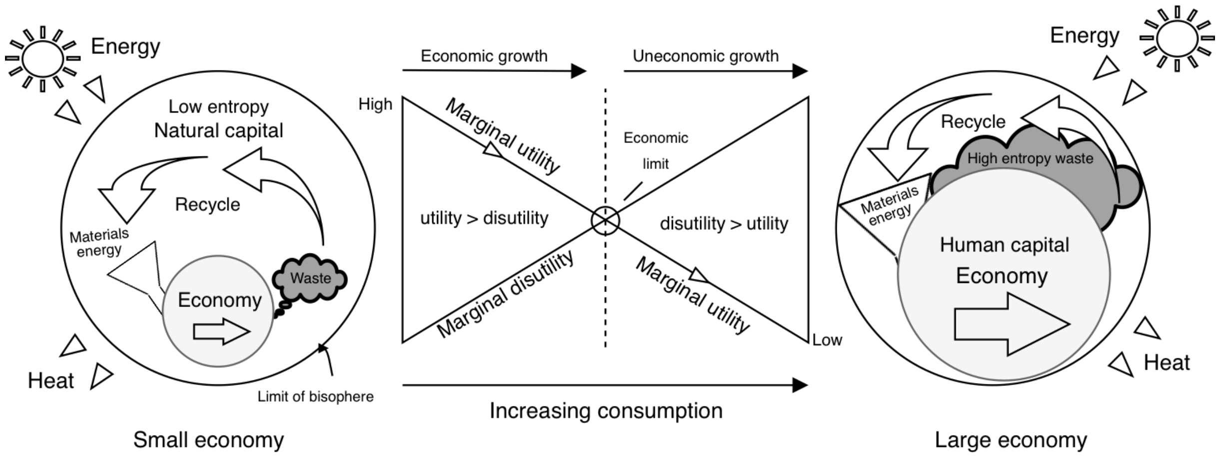

Figure 2.1 Effect of consumption on marginal utility (Adaption: Daly, 2015, fig.3)

This questions the disparity between the low financial price of many consumer products, and low level of repair when their utility ceases, when there is a high environmental cost to the biosphere (Scott et al., 2014). Added to this is increasing material flows, consumption and economic activity is not adding proportionally to human satisfaction, the law of diminishing marginal utility[4] (Figure 2.1). As Jan-Pieter Smits states when discussing economic growth, satisfaction and the well-being paradox[5]:

"There is a growing dissatisfaction in society. Society wants something else." (TUe, 2018, p.1)

Despite this paradox, the historical promotion of a consumer culture by governments and business to maintain employment and economic growth has fueled unsustainable material consumption. In 1955 the American economist Victor Lebow wrote:

"Our enormously productive economy demands that we make consumption our way of life, that we convert the buying and use of goods into rituals… We need things consumed, burned up, replaced and discarded at an ever-accelerating rate." (Lebow, 1955, p.3)

When coupled to advances in manufacturing and falling product prices, due to technical innovation and global integration, it is not difficult to see how household waste has become

[4] The satisfaction with successive consumption decreasing. See: Daly and Farley, 2011, p.19.
[5] Also known as Easterlin paradox, where life satisfaction remains stable whilst economic growth occurs. See: Lamb and Steinberger, (2017), p.3

an ever-increasing problem. More recently the European Commission has introduced a number of policy instruments to help move towards more sustainable consumption and waste reduction; such as the Waste Electrical and Electronic Equipment (WEEE) directive (2012/19/EC) to promote material recovery and reuse, Eco-design directive (2009/125/EC) and Energy Labelling Directive (2010/30/EC) focused on reducing product energy use. EU member states are required to legally recover 45% of products placed on the market, however, reaching waste recovery targets in practice has proved difficult with no increase in the recovery rate (37%) since 2009 (UNU, 2017).

Despite the efforts of UK charities such as WRAP in promoting sustainability, many household products are disposed of prematurely, often containing parts with high levels of embodied carbon[6] (Cole et al., 2017). In 2017 WEEE accounted for 2.1Mt of the UK's household waste (gov.uk, 2018), and although progress has been made in areas such as clothing and textiles, around 300kt of clothing still enters landfill every year (WRAP, 2017).

2.2 Greenhouse gases (GHGs) and assessing environmental impact

A direct consequence of increased economic and industrial activity powered by energy from carbon-based fuels such as coal and oil over the last 200 years, has been the increased concentration of greenhouse gases (GHGs) in the atmosphere (Etheridge, 1996).

"*Per capita production and consumption growth is a major driver for worldwide increasing GHG emissions*" (IPCC, 2014a, p.355)

Since the industrial revolution greenhouse gases such as carbon dioxide (CO_2) have risen from 280ppm to 409ppm (NOAA, 2018) an increase of 46%. Greenhouse gases trap heat within the atmosphere by absorbing infra-red radiation leading to an increase in global temperatures (global warming).

The World Meteorological Organization (WMO) created the Intergovernmental Panel on Climate Change (IPCC) in 1988, with the first report published in 1990. This report triggered discussion within the European Union on climate change and the need to reduce GHG emissions (see: European Council Decision 93/989/EEC). GHG monitoring and mandatory reporting systems were subsequently introduced for member states, with agreement between

[6] Embodied carbon in the context of this study refers to carbon emissions (CO_2 or GHGs) generated by the processes involved in producing a part/product; raw material extraction, manufacture and transportation. See: http://www.circularecology.com/carbon-footprint-v-embodied-carbon.html

industrialized countries[7] on binding targets for reducing GHG emissions following the Kyoto climate summit in 1997 and creation of the Kyoto Protocol. These agreements first came into force during 2005.

In 2007 the IPCC released its Fourth Assessment Report (AR4) stating:

"*Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures*" (IPCC, 2007, p.30).

The IPCC Fifth assessment (AR5) using advances in climate modelling[8], further confirmed the effect of anthropogenic induced radiative forcing of global temperatures, causing changes in the stability of the Earth's climate system. This posing significant risks to both human and natural systems (IPCC, 2014b), with threats to sectors including; freshwater resources, marine systems, food security, human security, health and economic services (IPCC, 2014c).

In December 2015 the Paris Agreement at the Conference of Parties (COP)21, set out areas and targets needed to strengthen action to combat climate change, such as limiting global temperature increases to below 2°C, and developed countries enhancing their mitigation efforts[9]. This agreement entered force during November 2016, and to date has been ratified by 179 parties[10]. The Paris Agreement is however not without its critics; Kevin Anderson stating that it "*implies a carbon budget far in excess of what is safe*" that presupposes reliance on "*highly speculative negative emissions technologies.. that may never exist.*" (Anderson and Nevins, 2016, p.210).

Greenhouse gas emissions include a basket of different gases as specified by the Kyoto Protocol and is linked to the United Nations Framework Convention on Climate Change (UNFCC) see Table 2.1.

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[7] China ratified acceptance in 1998, Canada withdrew in 2011 and United States has not ratified to date.
[8] AR5 used additional Earth system models, such as an interactive carbon cycle. See: https://www.rmets.org/sites/default/files/presentations/05022014-senior-cox.pdf
[9] To be achieved through Nationally Determined Contributions (NDCs) See: https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/ndc-registry
[10] For latest status see: https://unfccc.int/process/the-paris-agreement/status-of-ratification

Greenhouse gases	Global Warming Potential (GWP)*
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265
Hydrocarbons	16 - 376
Perfluoropolyethers (PFPEs)	9,700
Fluorinated ethers (HFEs)	<1 - 12,400
Gasses covered by Montreal Protocol	2 - 13,900
Hydroflurocarbons (HFCs)	4 - 12,400
Perfluorocarbons (PFCs)	6,630 - 23,500

*Note: values change as research progresses

Table 2.1. Gases classified as GHGs (IPCC, AR5, 2014)

Different gases create different levels of warming over a given time, with a period of 100 years normally considered. A global warming potential (GWP) index enables different GHG gases to be combined and expressed as a single Carbon Dioxide equivalent (CO_2e) figure. For example, if 2 kg of Methane is emitted it can be expressed as 56 $kgCO_2e$ (2 kg CH_4 = 2 x 28 $kgCO_2$).

Today the effects of climate change threaten to undermine the United Nations 17 Sustainable Development Goals[11].

"Climate change is one of the greatest challenges of our time and its adverse impacts undermine the ability of all countries to achieve sustainable development" (UN, 2015, p.8)

A report by business consultancy Deloitte looking at the notion of a more circular economy,[12] and potential for climate change mitigation, identified product repair and lifetime extension as "a significant means of *mitigating GHG emissions related to the production of material goods*" (Deloitte, 2016, p.6). Movements and actions within society, such as the community repair of household products, that offer the potential to reduce natural resource depletion and contribute towards a low carbon economy are therefore important contributors to this change.

[11] An agenda created by the UN for the future prosperity of all people and the planet set through internationally agreed goals and targets. See: https://sustainabledevelopment.un.org/post2015/transformingourworld

[12] An economy in which resources are kept in use for as long as possible through re-use, repair and recycling to reduce environmental impacts. See: http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

Researching a single indicator of Repair Café performance purely in terms of GHG emissions appears justified on the basis of its link to climate change, but it is inappropriate to assume that other environmental impact category indicators are not significant for inclusion in a more complete analysis. Depending on the methodology used, protecting human health, ecosystems and resources by assessing impacts from ozone depletion, acidification, eutrophication, water and mineral resource scarcity, to name but a few, could also be considered[13].

2.3 The rise of Repair Cafés and community repair.

With the backdrop of increasing concerns over sustainability there has been a movement to combat the throwaway culture, driven by both policymakers and community groups within Europe. Most notably are Sweden's moves to reduce consumption and CO_2 emissions by introducing tax reforms to encourage (nudge) the repair of clothes, bicycles and white goods (Starritt, 2016). In the Netherlands the concept of a Repair Café was developed in 2009. Created as a reaction to throwaway consumerism, Martine Postma promoted the preserving of repair skills, reduction of consumer waste and improvement of social cohesion by bringing 'expert' volunteers and owners of broken products together within local communities (Steinvorth, 2012). The format of repair events proved popular and the Repair Café Foundation was established in 2010 to motivate and support local communities in the formation of Repair Cafés across the world. There are presently 1586 Repair Cafés listed worldwide of which 52 are registered in the UK (RCF, 2018).

Alongside the establishment of Repair Cafés have been other community-based repair initiatives such as the London based Restart Project, a social enterprise founded in 2012 that organizes free events (Restart Parties) where volunteers help educate people on how to repair their electronic devices (Restart, 2018a). The creation of a safe social space for people to meet and share knowledge is an important part of the public appeal of community repair, in addition to the economic savings and environmental benefits being sought (Bell, 2015). Mirroring Repair Cafés, the Restart model has also expanded globally with events being held across Europe and the United States (Restart, 2018b).

The recent rise and success of innovative community repair has brought together different groups motivated by a collective vision to make changes at an international level. At the London Fixfest conference in 2017 the Open Repair Alliance was announced by founding

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[13] Work to harmonize impact assessment methods is currently ongoing through projects such as EU-FP7 see: http://lc-impact.eu/team-home

members; Repair Café Foundation, The Restart Project, Fixit Clinic (USA), iFixit (USA) and Anstiftung Foundation (Germany). The aim is to collectively influence future product design, improving reliability and reparability, and ensure policymakers protect consumer rights to repair the products they own.

"Together, we can present a much stronger case to manufacturers, designers, policy-makers and consumers" (Postma, 2017, p.1)

Central to building a strong advocacy case for change, is the collection and analysis of research data related to product failures and the potential benefits of product life extension; social, economic and environmental in the context of this study.

3 Literature review

3.1 Overview

The literature review starts by looking at predictions of reaching resource and planetary limits. The need for a sustainability framework to aid decision making by policymakers and business is discussed, leading to an overview of the 'circular economy' concept and present arguments in the literature about its limitations. Repair is placed within the context of a circular economy and its potential contribution considered in support of future de-growth. The role of repair within UK and EU legislation is explored followed by an overview of recent academic research and studies on repair and its potential to reduce GHG emissions.

3.2 Literature predictions of reaching limits

The issue of resource consumption and resource scarcity are not new, predicted to become problematic in the 21st century by Meadows et al. (1972) Club of Rome's report "The Limits to Growth". The report extrapolates consumption and population trends to find a point when resources no longer meet demand (see Appendix A), predicting a systematic collapse partly driven by the effects of increased pollution. Hayes (2012) raised criticisms of the assumptions and models used within 'Limits of Growth' but concluded through modern modeling that predictions of unsustainability with continuing economic growth remained valid.

The concept of a 'Planetary Boundaries (PB) framework' was first proposed by Rockström et al. (2009), there being thresholds for anthropomorphically forced changes beyond which we would be '*jeopardizing the safe operating space for humanity*'. This has further helped comprehend the notion of physical limitations to the resilience of the biosphere (see Appendix B). Defining where thresholds are with respect to motivating national and international policy change to prevent unsustainable behavior, and the reaching of tipping points, is however more difficult, as identified by Robért et al. (2013). As Steffen et al. (2015) point out:

"The PB framework does not dictate how societies should develop."

Robért et al. (2013) acknowledge the value of PBs, and highlight the need to couple the concept to a strategic decision-making mechanism for sustainable development, as without such a mechanism actions cannot be taken to avoid reaching and crossing planetary boundaries. The proposition is for planners, business and society to work within a Framework for Strategic Sustainable Development (FSSD), asking questions through a five-step process that leads to decisions based on a set of underlying sustainability principles (Figure 3.1).

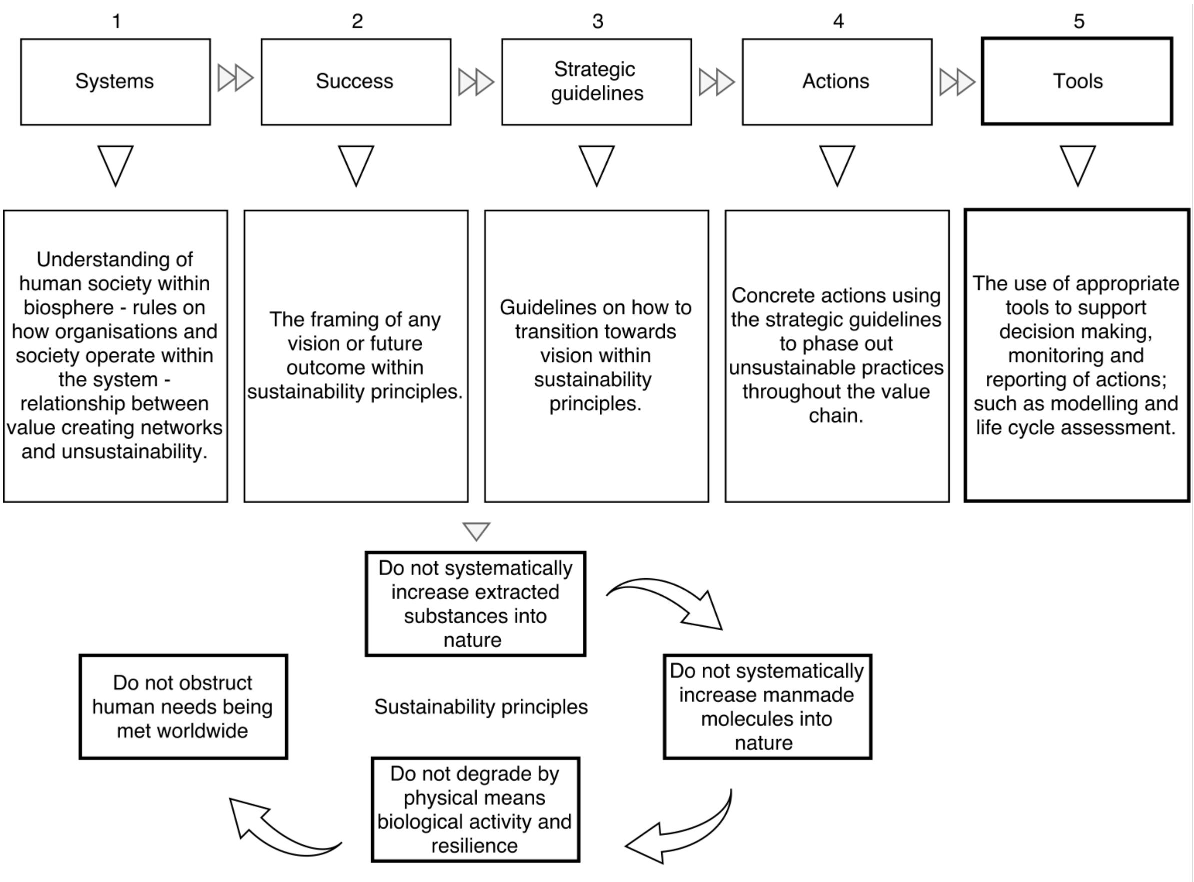

Figure 3.1 FSSD integration of sustainability principles
(Adaption: Broman at al., 2015, p.22)

3.3 The concept of a circular economy and repair

The origins of the circular economy (CE) are somewhat vague, possibly being inspired by earlier work: Meadows et al. (1972), Carson (1962), the ideas of Daly and ecologically based manufacturing strategies such as industrial ecology[14] proposed by Frosch et al. (1989). The idea of repeatedly using materials and preserving resources via loop-closing industrial practices has been a core principle of industrial ecology since its start, and most likely to have formed CE's underlying principles (Clift and Druckman, 2016).

The definition of CE is however not clear within the literature, with definitions such as: '*A mode of economic development that aims to protect the environment and prevent pollution*' (Mia et al., 2014) and '*A production and consumption system with minimal losses of materials and energy through extensive reuse, recycling and recovery*' (Haupt et al., 2017). The Ellen MacArthur Foundation (2013) has promoted a business orientated circular economy model that stresses the need to minimize the leakage of waste into nature through separate biological and technical circular loops within the economy (see Appendix C). The technical nutrient's cycle places maintenance-repair, reuse, refurbish-remanufacture and recycle in a hierarchy of secondary market[15] processes.

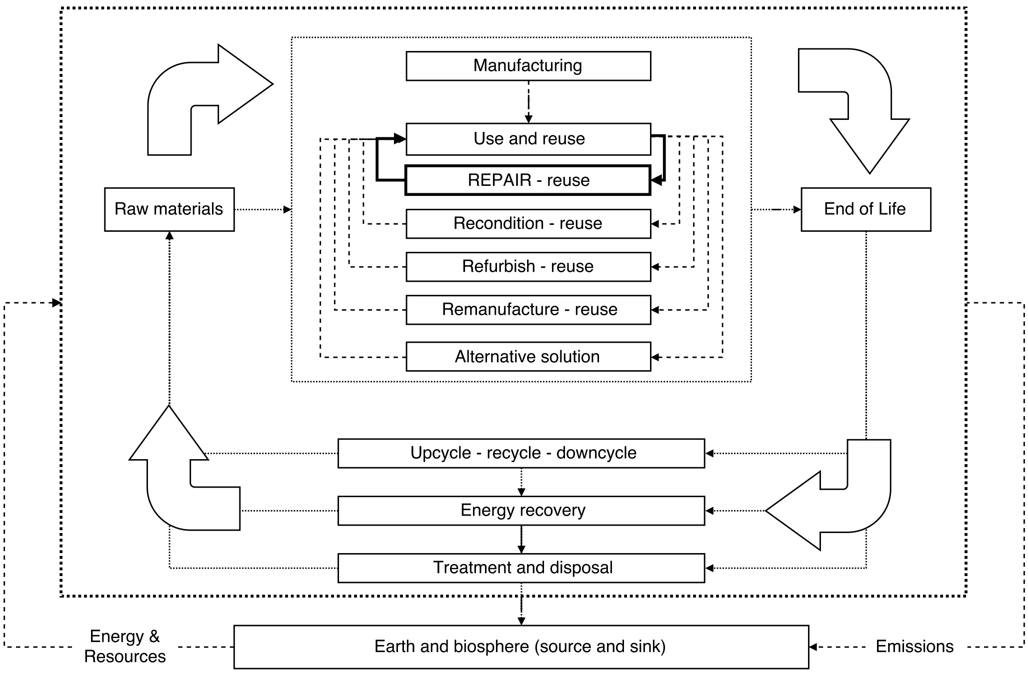

Figure 3.2 Repair within a circular economy (Adapted: Charfalkar et al., 2016)

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[14] Companies and organisations buy and sell waste products to one another in an attempt to produce a closed industrial cycle. See: Erkman, (1997)

[15] Waste that is recycled back into the economy. See: http://ec.europa.eu/environment/green-growth/raw-materials/index_en.htm

This concept of circularity turns waste into a resource, shifting the paradigm of a resource-based economy to one that is waste based (Park et al., 2014). See Figure 3.2.

Korhonen et al. (2018) argue using the FSSD framework that CE's contribution should be to reconfigure the linear flow of the economy towards a more circular one where the economy contributes to environmental, social and economic development. At present the social dimension is largely absent from CE's construct and application, whereas equity and social justice is considered a pillar of sustainability (Haynes et al., 2015).

A number of questions (Table 3.1) are raised within the literature of inherent CE limitations, such as; what happens when waste material flows are slowed through product life extension such as refurbishment and repair? Will the use of virgin raw materials not increase to compensate? Material and energy flow dependencies thus need to be understood to avoid an increase in global unsustainability, despite apparent progress as a result of burden shifting[16]. Added to this are the thermodynamic system constraints which in terms of recycling materials back to a useful state demands amounts of energy not presently available from purely renewable sources.

Some limtations to CE Concept	Explanation	Reference
Dependencies	Benefits depend on adequate skills and education, and varies across populations and geo-regions.	EEA, 2016
Lack of social dimension	Social pillar of sustainability is missing from redesign of production and service systems	Murray et al., 2017
Lack on international standards	Performance of CE needs to be measured to monitor effectiveness against agreed sustainability criteria	Kalmykova et al., (2018)
Long term sustainability	Proving a relationship between circular economy and sustainability	Geissdoerfer et al., 2017; Ewik, S. V., 2014
Possible conflict of objectives	For example achieving 100% renewable energy use might increase resource scarcity in critical areas.	Bjørn and Hauschild, 2011; EU, 2015
Respect of environmental limits	Consideration of scale of ecomony; rebound effect, Jevon's paradox	Karhonen et al., 2018
System boundary	Spatial problems pushed along product cycle. Temporal; short term non-cycling systems creating long-term cyclic ones	Karhonen et al., 2018
Thermodynamic	Cyclical systems comsume resources and create pollution	Karhonen et al., 2018, Robèrt et al., 2010

Table 3.1 Some limitations and challenges for the CE concept

There is clearly benefit in the CE concept being integrated and applied within industrial processes to reduce environmental harm, but the relationship between material circularity increasing business profitability and reducing environmental impacts is not presently well

[16] The shifting for example of impacts between the environment and socioeconomic sectors or shifting of impacts across spatial and temporal boundaries. See: https://ec.europa.eu/info/sites/info/files/file_import/better-regulation-toolbox-64_en_0.pdf

defined (Ewijk, 2014). What cannot be denied is that the repair and re-use of products is integral to the future policy implementation of CE practice and 'resources' optimization within Europe, as seen recently in Swedish government proposals (Kalmykova et al., 2018).

3.4 Energy, CE and need for degrowth

The International Energy Agency reported that global CO_2 energy related emissions rose to a high of 32.5Gt in 2017 due to robust economic growth of 3.4% (IEA, 2017). 81.6% of the UK's energy is derived from fossil fuels (Gov.uk, 2017a) and increased demand for energy world-wide is still met largely by fossil fuels (70%). This suggests that decoupling of economic growth and CO_2 is still some way away, although UN Sustainable Development Goal (8) calls for the '*decoupling of economic growth from environmental degradation*'.

Cooper et al. (2017) provide a quantitative assessment of energy use in the production of goods and services within a circular economy considering spatial boundaries (raised by Karhonen). Cooper concludes that CE approaches can potentially reduce UK primary energy consumption by 4%-6%, this being lower than the global potential of 5%-9%. This disparity is due to the high level of embodied energy[17] that resides in the imported products purchased in the UK. Approaches such as repair/refurbishment, reducing product consumption, should therefore be encouraged. Assumptions are made for the substitution of new product purchases with refurbished products in proportion to price, a refurbished product at 50% of the new price substituting 50% of new product purchases. This raises questions about the 'practical' success rates that can be expected when extending product life via repair, and what new product displacement (new product substitution) actually occurs?

In Europe the transition towards CE is still in its infancy, being driven predominantly from the bottom up by environmental NGOs calling for stricter legislation (Ghisellini et al., 2015). With global primary energy growth likely to exceed CE based resource efficiency improvements, there are doubts as to whether CE principles can prevent environmental damage. Bocken et al. (2017) maintain that in growth driven economies raw material extraction is still necessary, causing significant environmental damage even within a functioning CE. The notion of de-growth, the scaling down of production and consumption, therefore becomes important.

Escobar (2015) discusses 'transition activism' towards a de-growth framework and the role of initiatives such as the UK's Transition Town Initiative; which has supported the establishment of

[17] The amount of primary energy resource required to produce a product or service. See Rosado, (2009)

Repair Cafés (TN, 2017). This raises the question, does repair in the UK operating within its socio-economic context, and taking consumption due to the rebound effect[18] into consideration, offer an effective means of reducing production through the prevention (displacement) of new product purchases?

3.5 EU and UK waste policy and repair

Although academic debate continues about the merits of a circular economy, its principles of improving resource efficiency and resilience to resource scarcity have been adopted by policy makers within the European Union (EC, 2010; 2011; 2014; 2015$_a$). In December 2015 the European Commission launched a Circular Economy Package (CEP) advocating improved resource efficiency and eco-innovation through a series of action plans and legislative proposals to be met by 2030, including re-using and repairing of products (EPRS, 2016). The action plan is aimed at meeting the UN's Sustainable Development Goal (12), to 'Ensure sustainable consumption and production patterns'. With the UK presently set to leave the EU it is uncertain which obligations within CEP might continue beyond the UK's exit transition period (Ogleby, 2017). It is likely a degree of policy tracking will be necessary to enable trade. As Cowell et al. (2017) point out, depending on the Brexit narrative taken three scenarios are possible; 'Tracking the EU', 'Flatlining', 'Fragmentation and Regression' and 'Diverse green shoots'. Burns (2014) argued pre-referendum that with an absence of external pressure and the UK's historical efforts to weaken EU environmental policy, de-regulation is a more likely outcome.

Following UK devolution, Hill (2016) highlights the divergence of policies across the UK, the lack of good data and strategic direction from government in the form of economic interventions, and an over reliance on voluntary business initiatives. The UK's member state response to the EU's Waste Framework Directive (2008/98/EC) has been varied, with greater waste prevention measures being targeted by Scotland and Wales. Key to the waste hierarchy within directive 2008/98/EC (Figure 3.3) is 'prevention' of materials entering waste, to which the UK government acknowledged *repair* should be making a larger contribution, citing Repair Cafés as an example of civil society trialing an innovative solution to reducing waste (HMGov, 2013). Cole and Sherrington[19] emphasize that recycling has been given prominence in the UK, despite the need to be focusing on reducing consumption and increasing

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[18] A phenomenon whereby increases in resource efficiency do not necessarily result in a reduction in resource consumption. See Section 4.8.5
[19] Academics quoted by Loeb, (2017).

the re-use of products, which are both higher up the waste hierarchy (Loeb, 2017).

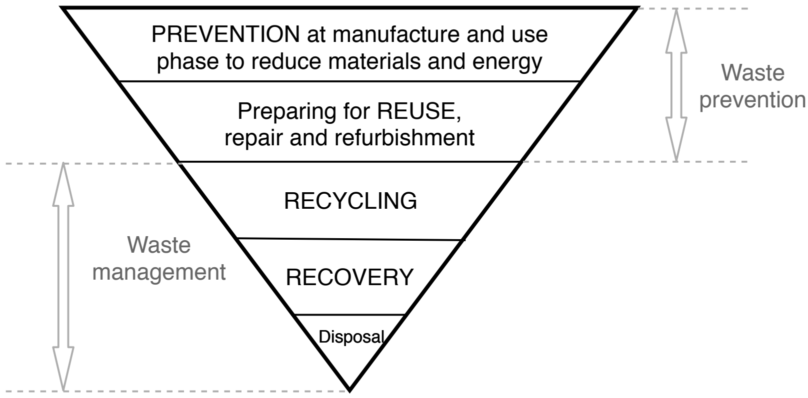

Figure 3.3 Waste hierarchy as specified in EU directive (2008/98/EC)

The Waste and Resources Action Programme (WRAP), a UK based charity working in conjunction with government, has been instrumental in highlighting consumer waste and need to reduce the lifecycle impacts of electrical and electronic equipment, including embodied GHG emissions, stated to be 196MT CO_2e (WRAP, 2018). Its Electrical and Electronic Equipment Sustainability Action Plan 2025[20] aims to help develop the circular economy by; improving product durability, reducing product return rates (products returned but not faulty), increasing product repair and re-sale, adopting more resource efficient business models such as leasing and increasing material re-use within supply chains.

3.6 Product design, repairability and obsolescence

Product design is increasingly identified with creating environmental issues through excessive resource use and waste creation. Brezet (1997) proposed four levels of Designing for the Environment (DfE), encompassing; Green design, Ecodesign, Sustainable Design and Sustainable Innovation. Ecodesign in particular has evolved as a way to assess design decisions and develop products to reduce their environmental impact (Hermann et al., 2014). Unfortunately for many products, such as household electrical appliances and personal electronics, commercial pressures have resulted in designs and manufacturing techniques that impede repair and disassembly (Ijomah et al., 2007). Increasing both the ability to repair

[20] See: http://www.wrap.org.uk/sustainable-electricals/esap

and re-use of products, and optimize their contribution to a circular economy, is highly dependent on Designing for Disassembly (DfD).

A general approach to 'design for disassembly' as proposed by Bouge, (2007) is shown in Table 3.2. This highlights the need to consider at the early stages of product design, the end of life optimization to; repair, reuse and recycle materials.

Design aspect affecting disassembly	Design guildelines
Product structure	Create modular construction Reduce number of components Reduce differences between similar products
Materials	Minimise number of different materials used Avoid mixed (difficult to separate) materials Eliminate use of toxic and hazadous substances
Fasteners	Minimise number of joints and connections between components Provide good visibility of and accessibility to all joints. Where possible eliminate hidden joints Use of fasteners rather than adhesives
Components should be:	Accessible Low weight and unpainted Robust and non fragile
Disassembly	Should be possible for automated dissassembly Possible with simple or commonly available tools Simple non complex procedure

Table 3.2 DfD design guidelines (Adapted: Bouge, 2007, p.288)

The European Parliament (EP) is aware of the conflict between product durability and planned obsolescence, the practice of manufacturers deliberately causing a product to become unusable within a given time period to increase consumption[21]. The EP is initiating legislative measures to make products; easier to repair, inform consumers about product reparability and their rights to repair (EP, 2017). This is further underwritten by plans to introduce standardized ratings for the repairability of energy using products (EC, 2015b).

"We must reinstate the repairability of all products put on the market"

Pascal Durand (EP, 2017)

[21] See: https://www.activesustainability.com/sustainable-development/battle-against-planned-obsolescence/

3.7 A review of repair studies

Despite repair and reuse being a clearly defined option within a more circular economy there is limited research in this area as identified by King et al. (2006), Watson (2008) and Mashhadi et al. (2016), when compared to numerous studies on the recycling of consumer products. King et al. (2006) examined repair alongside reconditioning, remanufacture and recycling within the legislative context of extended producer responsibility to reduce end of life waste. According to King et al., repair is the ‘most logical approach to closing the loop on product use’, supported by Stahel (1994) in minimizing energy use. It is inferred however that product repair is impractical due to barriers of fashion obsolescence, imposed by consumers and manufacturers, and variable repair quality.

Later research by Dewberry et al. (2016) looked specifically at the relationship between people and their products, and motivations to repair within the framework (and growth in popularity) of community events such as Repair Cafés. Although not representative of the general population, since most interviewees in the study were attendees, some of perceived barriers to repair described by attendees supported King et al. (2006). Barriers such as the non-availability of spare parts, products not being designed for disassembly and the inability to upgrade software. However, in contrast interviewees reported being motivated towards repair by emotional attachment, familiarity with an understood technology and in some cases it being cheaper to repair than replace. Emotional attachment to mobile phones for example and the data they contain is not uncommon (Wilson et al., 2017). Since repair is seen to slow consumption Dewberry et al. (2016) suggest that reparability should be tackled at the design and manufacturing level. Notably it is concluded that repair should be a fundamental part of business strategy to help close resource loops in a circular economy. This further supports Anastas et al. (2003) stressing the need to avoid the premature disposal of products to reduce material and energy flows through design that enables efficient maintenance and repair.

A separate study by Cole and Gnanapragasam (2017) undertook collaborative research with The Restart Project[22], this study was limited to Restart repair event attendees and again explored the barriers, attitudes and motivations of people to repair. The findings indicated low levels of trust in commercial repairers and a wide range in consumer confidence and knowledge in undertaking repairs. Importantly the social aspect and sense of community involved in sharing expertise and knowledge is seen as a key contributor to motivating repair

[22] A London based charity helping people reduce waste from consumer electronics through repair. See: https://therestartproject.org/

behavior alongside the need to repair broken products. This study again suggests repair as being important to a more circular economy and slowing consumption, connecting it to issues such as raising consumer awareness about repair and 'efforts to tackle climate change'. This connection is presently an assumption that appears poorly supported by quantitative studies considering community repair and its impact on reducing GHG emissions.

For an appraisal of the validity of repair and its potential to reduce GHG emissions, life cycle assessment (LCA) studies comparing various life extension options offer an insight. Biswas et al. (2013) compared repairing and remanufacturing of failed air conditioning compressors against replacement with a new item, looking at differences in GHG emissions. The study revealed repaired units, within different repair scenarios, performing as well as remanufactured and new units for the first 3 years of use, with significant savings of more than 87% compared to replacement with a newly manufactured unit. The study critically observed that product lifetime-extension period and durability is important when considering repair and any advantage compared with remanufacture. When longer-term time perspectives were considered remanufacture potentially offered greater benefit. WRAP, (2010) undertook a comparative repair or replace LCA study of domestic washing machines, finding that repair was environmentally beneficial in terms of GHG emission savings in half of the scenarios examined. It only being beneficial to replace when a newer washing machine was designed to consume significantly less energy during use.

Repair therefore offers potential benefits, but consideration needs to be made of the life-extension period and the type of products being repaired.

3.8 Literature summary

The literature shows that we continue to explore different frameworks and concepts for achieving a sustainable future whilst resources become scarcer, consumption increases and atmospheric GHG emissions force the Earth's climate and ecosystems towards further instability and tipping points. The UK and other developed countries sustainability policy is progressively adopting the circular economy model, despite there being limited agreement of its effectiveness, particularly if the model is seen to be in alignment with societies deep routed normative for continued economic growth. The literature suggests that sustainability can only be achieved if a steady state equilibrium can be reached between the Earth's carrying capacity and demand, requiring a reduction of raw material inputs and slowing of material and energy flows within the economy, of which repair can play a part.

Whilst the presence and value of Repair Cafés within a circular economy is acknowledged, it has attracted interest predominantly from researchers studying the social behaviors, barriers and motivations of people to pursue repair to restore product utility. Although life cycle analysis has compared individual products in the context of repair versus replacement and resulting GHG emissions, there appear to be gaps in the literature looking systematically at the collective repair of a diversity of products. Specifically, questions are raised about the actuality of; new product displacement, consumption due to the rebound effect, repair success rates across different products, life extension periods and the net potential to reduce GHG emissions.

As society is being driven to adopt CE through future policy and regulation, it is important to empirically evaluate the material 'virtuous' loop options such as repair and remanufacture within the context of the different business, social and physical frameworks they operate, as indicated by FSSD, to assess their effectiveness and guide strategic decision making.

4 Methodology

4.1 Scope of study – replace or repair scenarios considered

Given the stated aims and objectives, three potential end of life (EOL) scenarios for faulty household products are considered as shown in Figure 4.1.

- **Scenario 1** establishes a net GHG emissions base-line from which to compare the potential difference in GHGs created by taking a faulty product to a Repair Café. This scenario considers the immediate EOL disposal of a faulty product and its replacement with a newly manufactured item of the same specification. Here positive emissions are created from the embodied GHG emissions of the new replacement product, and those created from landfill and recycling[23] of the discarded product. The underlying premise of the methodology is that these emissions can be displaced if a product repair is successful.
- **Scenario 2** considers the potential increase in GHG emissions due to transportation and spare parts used when additional Repair Café activities fail to successfully repair

[23] The study considers recycling emissions as specified by Defra but does not account for recycling carbon credits.

a faulty product. The unsuccessful repair being followed by a new product replacement and disposal of the faulty product to landfill.

- **Scenario 3** Looks at the potential reduction in GHG emissions that occur when a successfully repaired product's life is extended for a period of time after failure, thereby displacing the GHGs emitted by the occurrence of Scenario 1.

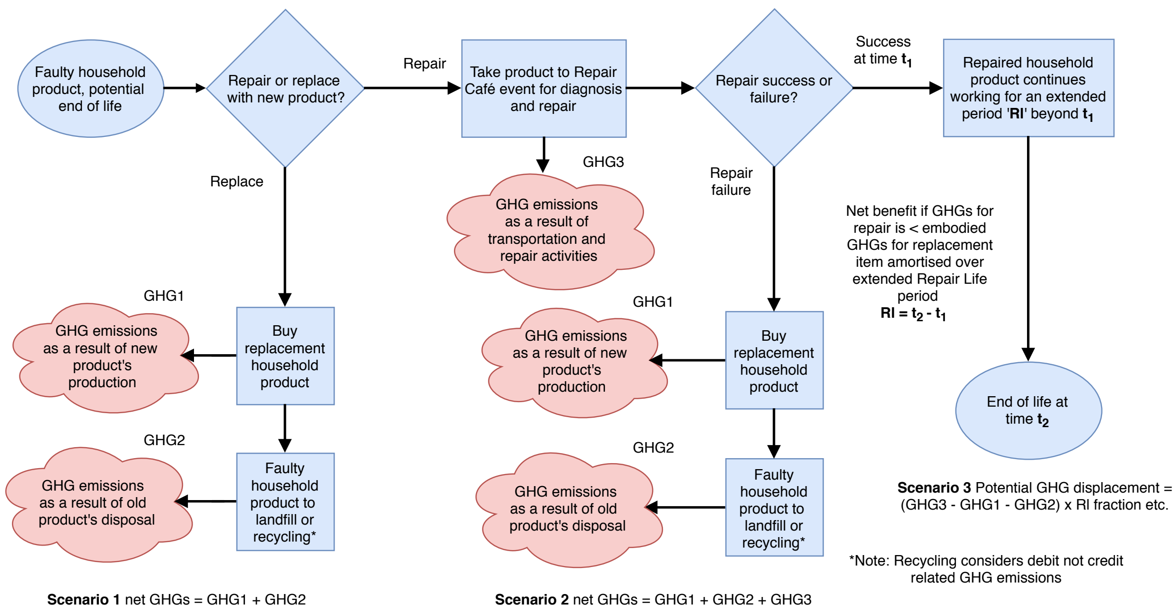

Figure 4.1 Product repair scenarios considered in the study

Both Scenarios 2 and 3 describe outcomes associated with taking a faulty item to a Repair Café. By examining Repair Cafe data, the aim is to establish how many products fall into each of the two scenarios (2 and 3) to calculate net overall repair related GHG emissions. Once repair related emissions are known these can be compared with the Scenario 1, in which faulty products would previously have been replaced, thereby determining whether Repair Cafés help mitigate GHG emissions.

This general methodology is taken since it considers GHG emissions arising from all attempted repairs and not just GHG displacement from those repairs considered to be successful. This approach takes into account the possible situation where a high number of attempted repairs of a particular product or products (with associated transportation and spare parts use) results in a small number of successful repairs, and therefore limited (if any) displacement of GHG emissions.

4.2 Repair outcome definitions

When undertaking repairs, Repair Cafés report a variety of different outcomes. For clarity their meaning in the context of this study is summarized in Table 4.1.

Repair outcome	Meaning within study
Attempted	Undertaking the fault diagnosis and repair (if considered possible), using spare parts if necessary, to try and fully restore the operation of a faulty product.
Successful or completed	An atttempted repair that has resulted in the product being restored to a fully operational condition enabling its continued use.
Partial	An attempted repair that has been undertaken and restored some limited operation, but the product has not been repaired to a fully working condition.
Not completed	An attempted repair has been undertaken, but the product remains faulty and unusable.
Advice given	An atttempted repair has been undertaken and not been completed, but the Repair Café has offered additional advice about alternative repair soloutions or viability of the product's repair.

Table 4.1 Definition of different repair outcomes

4.3 Study system boundary

The repair process initiates a series of direct material inputs, outputs and indirect consequences such as increase consumption due to the rebound effect. Those considered within the study system boundary are shown in Figure 4.2. The repaired product is considered with respect to new product displacement as a result of its life extension period, but no assessment of its energy consumption is made pre or post repair. The product’s in-use energy consumption is assumed to be a burden irrespective of repair intervention to maintain its provision of service[24]. GHG emission ‘overheads’ associated with completed repairs are assessed for spare parts used, transportation and consumption due to the rebound effect.

Consideration was given to include energy related emissions for heating and lighting at the repair venues. However, due to Repair Cafés generally operating in community or church halls

[24] It is assumed the continued functionality of the product is needed hence the product being taken for repair.

for only 2-3 hours each month, these emissions were not considered significant enough (400-800 grams $kgCO_2e$/session)[25] to warrant inclusion.

The approach is to build a representative picture via a quantitative assessment of the inputs, effectiveness of the repair, and owner behavior post repair to estimate GHG emissions occurring as a result of the service provided by Repair Cafés. The project time involved in collecting and sorting primary repair and questionnaire data precluded the use of an LCA based method of assessment due to time requirements, complexity and cost.

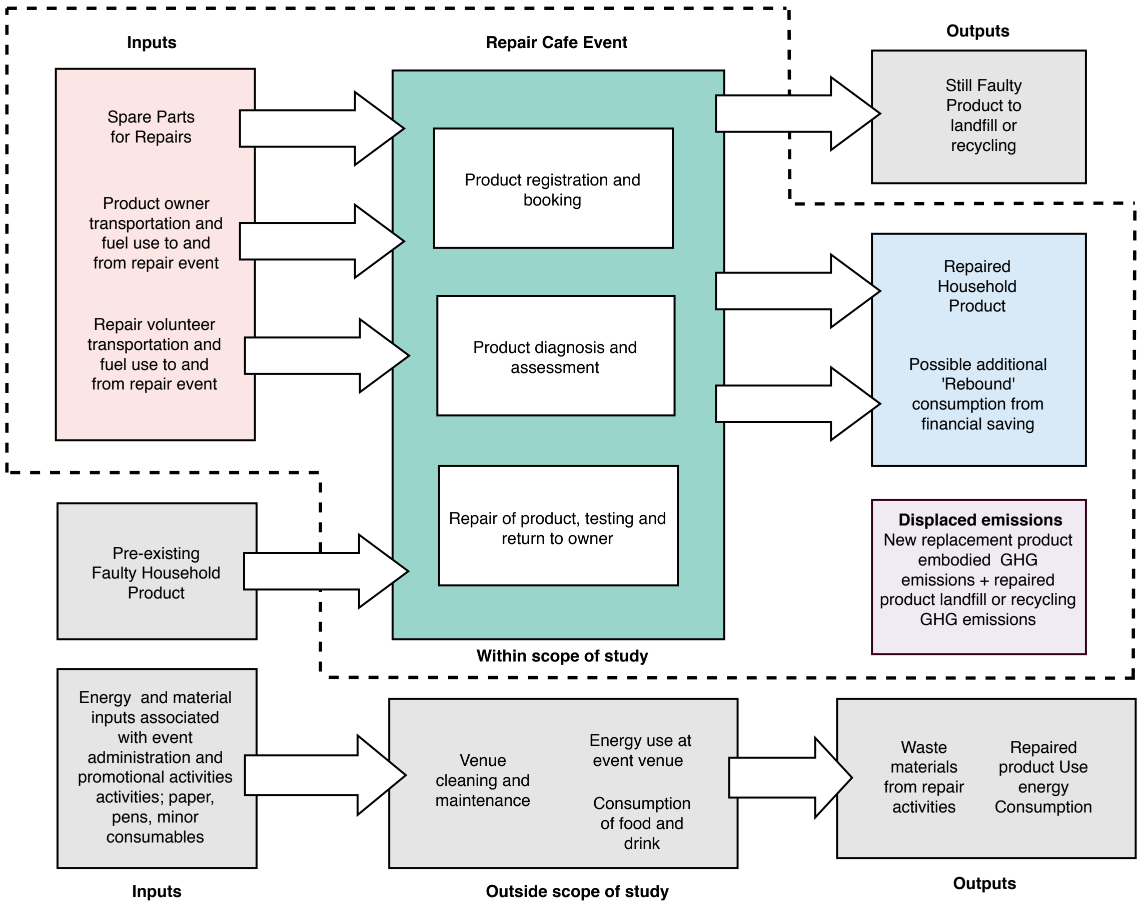

Figure 4.2 Study system boundary

A systems-based assessment is therefore adopted that considers GHG emissions and savings associated with: '*Taking a faulty household product to a Repair Café and having it repaired to a fully working condition*'. The focus is to consider the final life cycle stages of 'use-maintenance' and 'disposal', using the underlying principles of life cycle thinking[26] in reducing resource consumption and associated GHG emissions (see Appendix D). This study is not intended to be

[25] See: http://www.churchcare.co.uk/shrinking-the-footprint/ways-to-take-action/energy-efficiency/audit
[26] See: https://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/

compliant with LCA specifications such as ISO14040/44 and PAS2050, although some of the individual (secondary) LCA product GHG data used has been produced according to these specifications.

4.4 Scope of data collection

Central are two key areas of data collection from which an analysis of potential GHG emissions has been undertaken:

I. Product related quantitative data:

a) The types of products presented for repair at Repair Cafés.
b) The repair success rates for different product types.
c) The typical weight (kg) of each product type.
d) Embodied GHGs in spare parts used for repair.
e) Embodied GHGs in a new product-type replacement.

An alternative approach to reducing the amount of data needed to make the assessment would have been to use a previously published general repair success rate for Repair Cafés (Charter and Keiller, 2014). This was rejected, since it may have masked trends within the results for specific product types and product categories, which could benefit further discussion and research.

II. Product owner and repair volunteer quantitative data:

a) The distance (km) travelled to facilitate a repair at a Repair Café.
b) The type of transportation used.
c) Direct GHG emissions associated with transportation use.
d) Embodied vehicle GHGs associated with transportation distance.
e) Likelihood of indirect consumption (from rebound effect) as a result of visiting a Repair Café?
f) Likelihood that a successfully repaired product prevents a new product purchase?

4.5 Assumptions and limitations:

A range of initial assumptions and limitations was made: Products that were faulty when presented at a Repair Café, and not repaired, would have entered landfill/recycling irrespective of being taken to a Repair Café. Successfully repaired products 'would' have been replaced with an equivalent newly manufactured product. Also, that there is not a significant difference in energy efficiency between repaired products and their new product equivalents.[27] Transportation GHG emissions for new product purchases are part of the product's embodied GHG emissions, and GHG emissions associated with repair event energy usage and administration are considered as insignificant.

4.6 Product type categorization and sampling

An issue in terms of time resource for research in this area is large number of different household products taken for repair, and their categorization into suitable groups for analysis. It became apparent that it would not be feasible to categorize and determine the embodied GHG emissions for all product types seen at Repair Cafés using product specific LCA studies. Using generalized carbon footprint figures for broad product categories obtained from input output modelling (IOM) would have avoided this issue, but only provide a coarse approximation of embodied GHG emissions. This is a weakness of IOM noted by Minx et al. (2009 p.209). For this reason, the following approach was adopted:

From each Repair Café's dataset, the 25 most common product types seen for repair, by frequency, were selected. The individual data sets for the 25 most commonly repaired items were then fully merged on a 1:1 basis to produce a consolidated product-type master list. This clustered approach to analysing the individual data sets first, was used to help ensure a representative sample of product types from each geo-region were used in the analysis. Thus, considering the possibility of differences between the types of products taken for repair across the UK. Embodied GHGs for each product type were then sourced or calculated, using information from a number of fully referenced sources (see Section 5.3.2).

4.7 Questionnaire data collection

The target population for the questionnaire were individuals who had previously taken a faulty product to a Repair Café. The online questionnaire (see Appendix E), designed using Google Forms[28], was directed at this population group via individual Repair Café; social media, mailing lists and newsletters (see Appendix F) for a period of 8 weeks, starting from

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[27] Repair Cafés tend not to repair larger white good items such as fridges and washing machines but low powered electrical items such as radios and occasionally used items such as hedge trimmers (Charter et al., 2015)

[28] Google application with ability to create free unlimited online surveys. See: https://www.google.co.uk/forms/about/

mid-December 2017. This was done to help provide a consistent demographic between the questionnaire and Repair Café repair datasets. A £50 retail voucher prize incentive was offered for completed questionnaire submissions. Respondents thus *volunteered* to answer the questionnaire.

Since visitors to a Repair Café may have visited on more than one occasion, or have taken more than one item for repair, each respondent was asked to report on 'their most recent visit and very last product to be looked at by a volunteer repairer'. This was done to help minimize any one individual's weighting in the data, errors of recall and any tendency towards socially desirable responding (SDR) with respect to answers (van de Mortel, 2008). Respondents were however able to indicate how many repair items were taken on their last visit, as this is considered as a factor within the transportation calculation of GHG emissions per repaired item (see Section 5.4.2).

4.8 Data analysis approach

4.8.1 Transportation - passenger vehicles

Each respondent was asked to classify the type of transportation used to attend the Repair Café. This included, if used, information about the type of vehicle, its engine type and the distance travelled. Vehicles were presented in different categories within the questionnaire (see Table 4.2) based around Society of Motor Vehicle Manufacturer and Trader *grams* CO_2/km emissions groupings (SMMT, 2017a). Where additional categories were needed to provide an appropriate range of response options, these are as grouped by vehicle manufacturers and motoring publications such as What Car?

European Union regulations have required vehicle manufacturers to lower overall CO_2 emissions via the setting of mandatory emission reduction targets for new cars since 2009 (EU, 2009). Since the average age of passenger cars in the UK in 2017 is 7.8 years (SMMT, 2017b) UK government CO_2 emissions test data from 2009 (VCA, 2009) is used to calculate the category average *grams* CO_2/km for each vehicle group (the study assumes 1 $kgCO_2$ = 1 kgCO2e). To help improve the accuracy separate average tailpipe *grams* CO_2/km figures are calculated for Diesel and Petrol vehicles within each vehicle category (see example Appendix G).

Allowance is also included for lower CO_2 emission Hybrid and Electric vehicles by producing separate *grams* CO_2/km group averages for these engine types.

Questionnaire vehicle categories	Examples given	Non car options
Small economy car	Nissan Micra, Ford Ka, Citroen C1	Motorcycle
Compact car	Ford Fiesta, VW up!, Kia Picanto	Bicycle
Mid-size car	Ford Focus, VW Golf	Moped
Full-size car	Ford Mondeo, Vauxhall Insignia	Bus
Luxury car	BMW 5 series, Audi A8, Jaguar XJ	Tram
Sports car	Porsche Boxster, Audi TT, BMW Z4	Train (overground)
SUV Sports Utility Vehicle	such as VW Tiguan, Ford Kuga, Toyota RAV4	Train (underground)
4x4	Range Rover, Land Rover, Volvo XC90	Mobility scooter (electric)
Van	Ford Transit, Renault Trafic	Wheelchair
Pick-up truck	Mitsubishi L200, Nissan Navara	Walked

Table 4.2 Transportation categories used for questionnaire

Additional non-car options for transportation were included such as cycling and public transport using emission figures derived from Travelfootprint[29] (see Appendix H).

4.8.2 Embodied GHG emissions for transportation

An effort has been made to add a proportion of embodied GHGs for vehicle production to tailpipe emissions for return distances travelled, since this is potentially a significant contributor to overall emissions associated with each vehicle journey. The embodied figures used are calculated using a baseline mid-size 1240kg car (VW Golf/Ford Focus) provided by a Ricardo Engineering study (Ricardo, 2013). This study found that:

> *'For a standard mid-sized gasoline ICEV (internal combustion engine vehicle) the embedded carbon in production will be around 5.6tCO_2e, around three quarters of which is the steel in the vehicle glider'.*[30]

Since vehicle 'steel' weight is the dominant factor for embodied GHG emissions during vehicle production, the embodied GHGs for car categories in the questionnaire are linearly scaled according to weight from this *5.6t*CO_2e baseline figure. Diesel and Petrol vehicles are

29 An online tool funded by Clear Zones Partnership and Defra. See: https://www.camden.gov.uk/ccm/content/press/2009/march/travel-calculator-wins-top-prize/

30 From press release (LowCVP, 2011) for Ricardo Engineering report (Ricardo, 2013)

calculated separately within each category due to diesel vehicles being heavier and therefore having higher average embodied GHGs (see Appendix I).

The embodied GHGs 'Ve' ($kgCO_2e/km$) figure for each vehicle category is calculated as:

$$Ve = \frac{Vm\ .\ 5600}{1240\ .\ Vl} \qquad \text{equation-1}$$

Where: Vm = Average vehicle mass for vehicle category (kg)

Vl = Vehicle life expectancy[31] (kms)

1240 = vehicle weight (kg) that resulted in 5600$kgCO_2e$ of GHG emissions

Transportation tailpipe Tp (grams CO_2/km) is calculated as:

$$Tp = Vc\ .Rd \qquad \text{equation-2}$$

Where: Vc = Vehicle category (grams CO_2/km)

Rd = Return distance (km)

4.8.3 New product displacement factor

The system boundary considers the displacement of avoided embodied GHGs for replacement products when faulty products are successfully repaired. New Product Displacement is not assumed to be on an equal basis to successful repairs (Weidema, 2000), since displacement is negated if following repair an owner still buys a new product or if the repair fails shortly afterwards.

Two variables are included within the Displacement Factor 'Df':

Firstly, the Repair life extension period (Rl) occurring due to repair.[32] This accounts for differences in life expectancy of a repaired product compared to a new product, since this directly affects the quantity of displaced GHG emissions.

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[31] Vehicle life assumption of 150,000 km See: Moving to a life cycle assessment of vehicle emissions https://www.greencarguide.co.uk/features/moving-to-a-life-cycle-assessment-of-vehicle-emissions/

[32] Questionnaire responses provided very limited primary data in this area (since many repair visits were relatively recent) and did not provide a reliable indication of post repair life extension.

Secondly, the Probability (Pb) that the repaired product will prevent a new product purchase. An estimation of owner behavior is made via the questionnaire asking respondents to indicate whether following a successful repair it '*prevented a new product purchase?*'. This provides an owner probability (0-1), based on the percentage of respondents in the sample who did not purchase a new product following repair.

This probability is included within the calculation for Displacement Factor '*Df*'.

$$Df = Pb\ .\ Rl \quad \text{equation-3}$$

Where: *Pb* = Probability of owner not buying a new product (0-1)

Rl = Repaired product's life extension as fraction its original design life.

The study uses a single displacement factor for all products. In practice different products are likely to exhibit different displacement factors, when considering externalities such as fashion and legislative changes.

Since insufficient quantitative data was available for individual product 'Rl', for the purposes of this study, a figure of 1 is being used[33]. A sensitivity analysis is therefore provided to examine the effect of 'Rl' being less or greater than 1.

4.8.4 Landfill and recycling GHG emissions

Landfill (*Lf*) GHG emission figures for repairs are calculated based on the actual or estimated product mass for each repair, multiplied by the Defra waste GHG ($kgCO_2e/t$) for the Defra category most closely representing the product waste type (see Appendix J). Since Defra provided two figures, one for landfill and one for closed-loop recycling, the average waste figure of landfill and closed loop recycling is allocated by product weight according to the UK waste disposal rates of 45.2% to recycling and 54.8% to landfill (Defra, 2018).

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[33] An example would be mobile phones with a potential lifespan of 10 years (Paiano, A, et al., 2013) and typical 'use' life of less than 3 years (Bian et al., 2016) so Rl=2.3. Green Alliance reports that repair of smartphones (such as battery and screen) can be worthwhile for up to 7 years. See: http://www.greenalliance.org.uk/resources/A%20circular%20economy%20for%20smart%20devices.pdf

4.8.5 Indirect rebound effect

The *rebound* or *take-back* effect describes a phenomenon whereby increases in resource efficiency do not necessarily result in lower resource consumption. This is due to additional economic activity from behavioral changes, initiated by increases in resource efficiency (Binswanger, 2000). Study of the rebound effect often looks at the direct and indirect relationship between technologically driven energy efficiency improvements, and actual energy consumption (Santin, 2013, Freir-Gonzalez, 2017).

The questionnaire asked respondents to indicate whether they 'perceived' that they saved money as a result of visiting a Repair Café, and what, if any, additional goods or services were consumed as a result of the perceived financial saving? Since consumption of additional goods and services incurs GHG emissions, this indirect rebound effect will offset some of the emissions savings (Druckman et al., 2011) offered by repairing rather than replacing products. For this study, indirect rebound (Rb) is considered in terms of GHG emissions and proportioned according to an estimation of '£' saved (based on recorded donations, see Appendix Y) and the carbon intensity/£ for the goods or services purchased. Figures used are those provided by Carbon Footprint[34]. *Direct* rebound effect is not considered, since repair does not change the baseline energy efficiency of an item in most repair cases[35].

Equation used to calculate Rebound '*Rb*' ($kgCO_2e$)

$$Rb = Ps\ .\ Sc \quad \text{equation-4}$$

Where *Ps* = Perceived saving (£) spent

Sc = GHG intensity of service or goods consumed ($kgCO_2e$/£)

4.8.6 Calculating embodied GHGs for new replacement product types

For each product type in the consolidated product list an average product weight, and embodied GHG emissions are determined using referenced sources (Appendix K). These

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34 *Available at: https://www.carbonfootprint.com/calculatorfaqs.html*

35 *An exception if it were being considered would be lighting products where more efficient bulbs are used for repair of older lighting appliance due to EU directive (2005/32/EC)*

figures are used to calculate the embodied GHGs for a New Product equivalent '*Ne*' (kg CO_2e) for successfully repaired items as:

$$Ne = Pm \,.\, Pe \qquad \text{equation-5}$$

Where *Pm* = Repaired product mass (kg)

Pe = Embodied GHGs (kgCO_2e/kg) for product type

4.8.7 Calculation of potentially mitigated GHGs per completed repair

The total GHG emissions resulting from Repair Café activities are subtracted from the total GHG emissions displaced, by the prevention of new product purchases, to give net average GHG emissions per completed repair as shown in the following steps:

Step 1: Calculate total sum of potential GHGs mitigated '*Pn*' (kgCO_2e) by avoidance of new product purchases and landfill diversion, multiplied by the Displacement factor.

$$Pn = Df \sum_{i=1}^{i=ns} (Ne_i + Lf_i) \qquad \text{equation-6}$$

Where: *ns* = Number of completed product repairs for all attempted repairs

Ne = New product embodied GHGs (kgCO_2e) for product type repaired

Lf = Landfill GHG emissions (kgCO_2e) displaced for product type repaired

Df = Displacement factor

Step 2: Calculate total sum of repair related GHG emissions '*Re*' (kgCO_2e); transportation, spare parts use and consumption due to rebound effect resulting from all attempted repairs.

$$Re = \sum_{i=1}^{i=nj} (Tp_i + Ve_i) + \sum_{i=1}^{i=nt} (Sp_i + Rb_i) \quad \text{equation-7}$$

Where nt = Total number of attempted repairs

nj = Total number of journeys for all attempted repairs

Tp = Transportation tailpipe CO_2 emissions (kg) for journey distance (km)

Ve = Embodied GHG emissions (kgCO_2e) for vehicle proportioned to journey distance

Sp = Embodied GHGs in spare parts used (kgCO_2e)

Rb = Rebound GHG emissions (kgCO_2e) as a result of perceived money saved that result in purchase of goods/services

Step 3: Calculate average potentially mitigated GHGs '*Pm*' (kgCO_2e) per repair for a given number of attempted repairs:

$$Pm = \frac{Pn - Re}{ns} \qquad \text{equation-8}$$

Full equation can be written as:

$$Pm = \frac{Df \sum_{i=1}^{i=ns}(Ne_i + Lf_i) - \sum_{i=1}^{i=nj}(Tp_i + Ve_i) - \sum_{i=1}^{i=nt}(Sp_i + Rb_i)}{ns}$$

4.8.8 Repair environmental GHG break-even point

Previous studies (Zink, 2014, Griese et. al., 2004) have noted that repairing and reusing products is only beneficial when the net impacts of the repair over the life extension period are equal to the net primary impacts of purchasing a new product and using it over the same time period. With respect to repairs in this study the approach used[36] is based upon the total embodied GHGs for the repaired product, and considering a '*GHG payback period*'*:*

"*A simple rule of thumb to determine when product lifetime extension is environmentally sound*" (van Nes et al., 2006)

That is, to consider a break-even point in time after which repairing a product would be environmentally unsound as a result of causing more GHG emissions than would be mitigated by purchasing a new product.

[36] This approach was developed following an initial dialogue with James Suckling at Univ. Surrey CES

For an individual repair, the break-even point at which a product's annualized emissions equal those of the repair can be defined as when:

$$Re - Ne\left(\frac{Et - Tf}{Et}\right) = 0 \quad \text{equation-9 [37]}$$

Where Ne = Embodied GHGs ($kgCO_2e$) for new replacement product

Re = Repair related GHG emissions ($kgCO_2e$)

Tf = Repaired product use time before failure (yrs)

Et = Expected lifetime of new product (yrs)

An alternative way of expressing this is to say that it is worth repairing a product if the total repair emissions (*Re*) are less than the ratio of repaired life time to design life time multiplied by a new replacement product's embodied annualized GHG emissions (equation 10).

$$Re < Ne\left(\frac{Et - Tf}{Et}\right) \quad \text{equation-10}$$

Equation (9) can be re-arranged to find the time *Tf* period within the product's life at which break-even and a net environmental benefit can occur, after which there is no net GHG emissions saving.

$$Tf = Et\left(1 - \frac{Re}{Ne}\right) \quad \text{equation-11}$$

In practice it is useful to estimate how long products need to work following repair to be GHG emissions neutral. Repair life extension period '*Rl*' needed:

$$Rl = Et - Tf \quad \text{equation-12}$$

Substituting equation (11) for term *Tf*, repair life extension period (*Rt* in days) can be expressed as:

$$Rt = 365.Et\left(\frac{Re}{Ne}\right) \quad \text{equation-13}$$

[37] Equation (9) assumes 'Ne' for the repaired product is the same as for new replacement.

Since ascertaining the repair life extension period of repairs is not possible from the available data, the break-even point or ‘payback’ time period is calculated for a range of different product categories using equation-13.

5 Results and data analysis

Repair data was received from 13 (UK) Repair Cafés for repairs carried out from August 2014 to November 2017. The total number of repairs recorded was 2852, covering over 230 different products. The online questionnaire received a total of 222 responses from visitors and volunteers to 20 different (UK) Repair Cafés from December 2017 to February 2018.

5.1 Most common household products seen for repair

To enable a pragmatic analysis to be carried out the 25 most frequently seen household products from each Repair Café's dataset were selected to provide a representative sample of products taken for repair. This resulted in a list of the 79 most commonly seen products, representing 2356 of recorded repairs on which to conduct the analysis. Table 5.1 shows the individual product types and the frequency seen for repair.

No.	Product repair	Frequency	Percent	No.	Product repair	Frequency	Percent
1	Bicycle pedal (non elec)	206	8.7	41	Hi-Fi amplifier	19	0.8
2	DAB/FM portable radio	148	6.3	42	Hair straightener/tongs	19	0.8
3	Trousers	118	5	43	Rucksack	18	0.8
4	Table lamp (metal)	114	4.8	44	Table (wood/metal)	18	0.8
5	Laptop	98	4.2	45	TV (LCD)	16	0.7
6	Vacuum cleaner	87	3.7	46	Phone (DEC)	16	0.7
7	Necklace	87	3.7	47	Standard lamp	15	0.6
8	Sewing machine	70	3	48	Coffee machine (elec.)	15	0.6
9	CD/DVD player	61	2.6	49	Curtains	14	0.6
10	Toaster (elec.)	61	2.6	50	Microwave oven	14	0.6
11	Food mixer/blender (elec.)	55	2.3	51	VCR cassette recorder	13	0.6
12	Chair (mixed materials)	50	2.1	52	Table lamp (wood)	13	0.6
13	Toy (electronic/plastic)	47	2	53	Earrings (metal)	13	0.6
14	Kettle (elec.)	42	1.8	54	Razor (elec.)	13	0.6
15	Hedge trimmer (elec.)	39	1.7	55	Toy (soft)	12	0.5
16	Iron (steam)	37	1.6	56	Cardigan	12	0.5
17	Clock (electronic)	37	1.6	57	Extension cable	12	0.5
18	Torch (battery)	35	1.5	58	Secateurs	12	0.5
19	Shirt	32	1.4	59	Camera (modern 35mm)	11	0.5
20	Mower (electrical)	31	1.3	60	Shredder (paper)	11	0.5
21	Watch (battery)	29	1.2	61	Clock (mechanical)	11	0.5
22	Jacket (cloth)	28	1.2	62	Ornament (china/glass)	11	0.5
23	Jumper	27	1.1	63	Camera (digital)	10	0.4
24	Handbag	26	1.1	64	Shoes	10	0.4
25	Bag (cloth)	25	1.1	65	Fan (elec.)	10	0.4
26	Hairdryer	25	1.1	66	Dehumidifier	9	0.4
27	Coat	24	1	67	Vacuum cleaner (battery)	8	0.3
28	Printer	24	1	68	Clothes steamer	8	0.3
29	Drill (elec.)	24	1	69	Glasses (specticals)	7	0.3
30	Hi-Fi music system	24	1	70	Speakers	7	0.3
31	Dress	22	0.9	71	Spade/fork (non powered)	7	0.3
32	Lighting (decorative)	22	0.9	72	Musical instrument (wood)	7	0.3
33	Brooch	22	0.9	73	Anglepoise Lamp	7	0.3
34	Smart phone	22	0.9	74	Blanket (quilt/duvet)	6	0.3
35	Skirt	21	0.9	75	Pressure washer (elec.)	6	0.3
36	Tablet (iPad)	21	0.9	76	Shears	6	0.3
37	Electric heater/radiator	21	0.9	77	Loppers	6	0.3
38	Tape/cassette recorder	21	0.9	78	Staple gun	6	0.3
39	Bracelet	20	0.8	79	Suitcase	6	0.3
40	Headphones (over-ear)	19	0.8				
					Total	2356	100%

Table 5.1 79 most commonly seen products for repair

As seen in Table 5.1, Bicycles are the most common household product taken for repair (8.7%), followed by DAB/FM portable radios (6.3%) and Trousers (5%). The relatively high number of sewing machines seen (3%) possibly reflects the recent resurgence in home sewing and dressmaking (Wood, 2017).

To further aid analysis and enable a comparison between different product categories, the individual product types were also assigned to one of 10 general product categories (see Appendix M). The percentage of repairs represented within each product category are shown in Table 5.2.

General product category	Number of products	Perecentage (%) of items taken to UK Repair Cafés
Household appliances	760	32.3
Clothing & textiles	395	16.8
Audio and AV/Photo	349	14.8
Bicycles	206	8.7
Computing, IT and mobile	181	7.7
Jewellery	178	7.6
Garden & DIY power tools	100	4.2
Other household	82	3.5
Furniture	68	2.9
Tools (non elec.)	37	1.6
Total	2356	100.0

Table 5.2. Percentage of products taken to Repair Cafés by category

The product category needing the greatest number of repairs, by a large margin, is Household appliances (32%); representing electrical products such as vacuum cleaners, kettles, sewing machines and food mixers. This is followed by Clothing and Textiles (17%) with products such as trousers, shirts, skirts and jackets. Audio and AV/photo (15%) follows closely behind, with electronic products such as DAB/FM Radios, CD/DVD players and Hi-Fi music systems. Furniture (2.9%) and non-electrical Tools (1.6%) categories represent the least frequently seen product types.

5.2 Repair Cafés repair outcomes

Repair Cafés can prevent the need for owners to purchase a new product when a faulty product is successfully repaired. This displaces embodied GHGs in the replacement product. Across all Repair Cafés, 67% of product repairs were recorded as being successfully completed, and 33 % as partially or not completed (Figure 5.1). A number of product repairs (191) had an 'unknown' repair outcome and were removed from the repair analysis, leaving 2165 repairs.

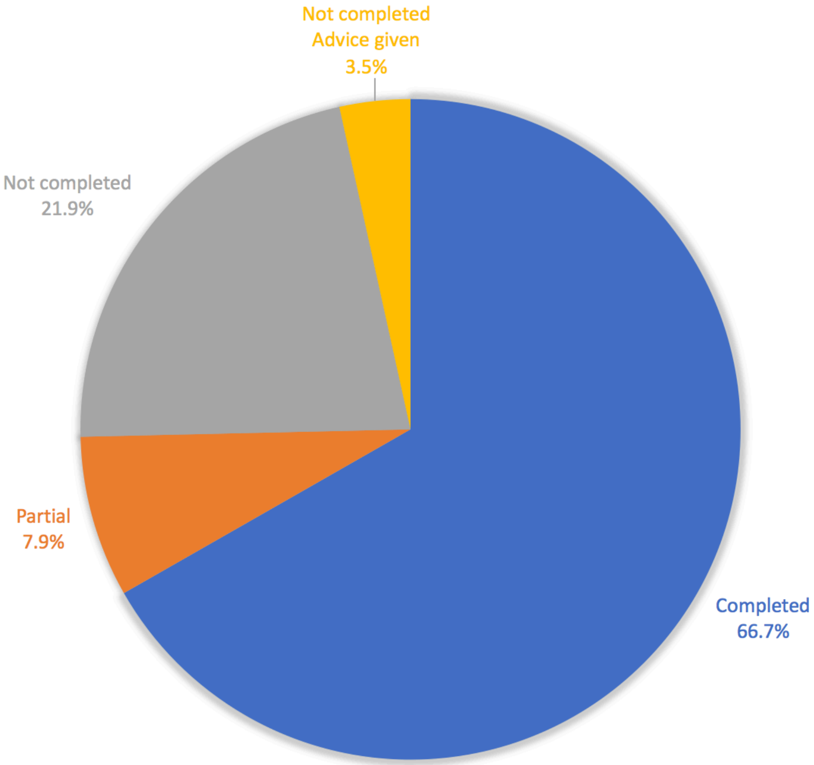

Figure 5.1 Repair outcomes for commonly seen products (n=2165)

The spread of successfully complete repairs across different Repair Cafés ranged between 53 and 75%, when analyzing data from Repair Cafés that had attempted more than 100 product repairs (see Appendix N).

To provide an insight into product types and their relative repairability at Repair Cafés, repair outcomes for each product type were analyzed. To ensure a representative comparison only products with more than 15 attempted repairs have been considered. The top 10 most successfully repaired products are shown in Figure 5.2. Clothing and textile products such as trousers, coats and dresses show the highest (>95%) completed repair rate. For comparison the bottom 10 least successfully repaired product types are shown in Figure 5.3.

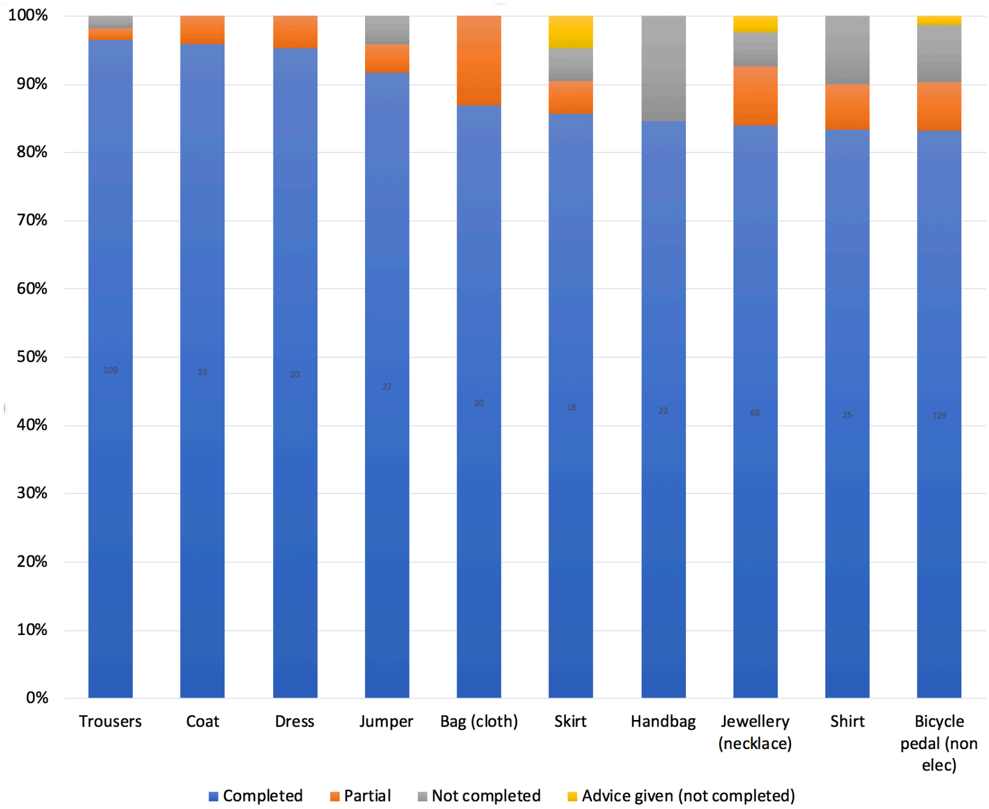

Figure 5.2 Top 10 most successfully repaired products (n=2165)

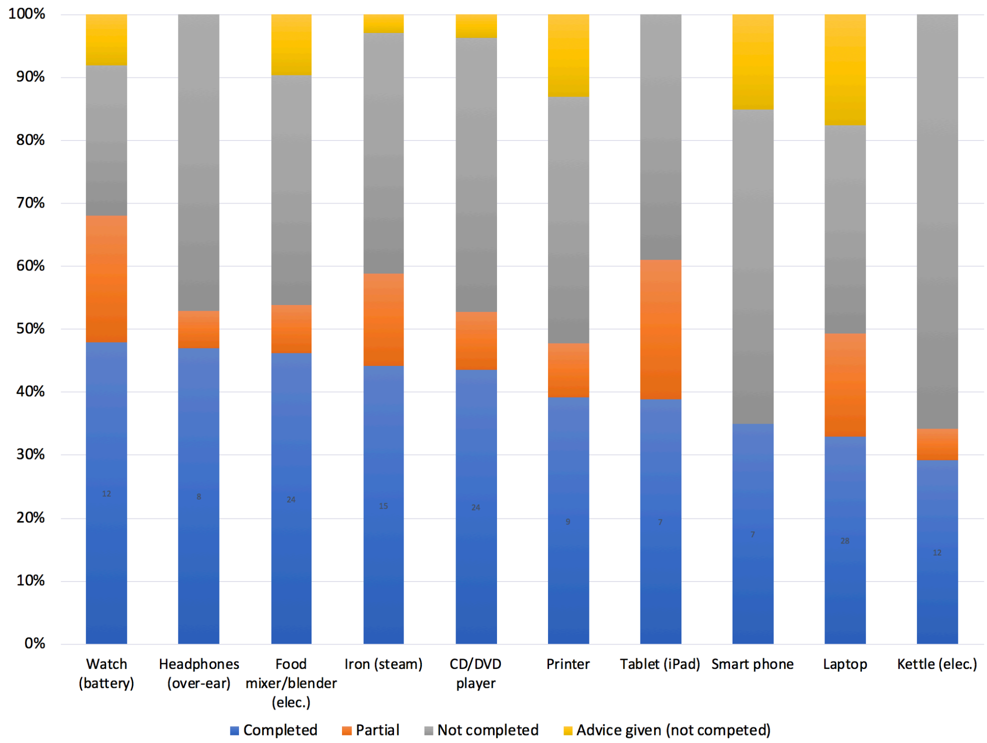

Figure 5.3 Bottom 10 least successfully repaired products (n=2165)

Electrical and electronic products such as kettles, laptops, smartphones, tablets and printers show the lowest (<40%) completed repair rate. Given the relative technical simplicity of kettles it raises the question of why kettle reparability is so low, particularly when the repairability of more complex electrical and electronic products is significantly higher; such as DAB/FM Portable Radios (61%), Electric Mowers (65%), Vacuum Cleaners (71%) and Hedge Trimmers (79%).

Looking at product repair success rates for the general product categories (Table 5.3) shows Clothing and textiles (89%) to be the most successful followed by Bicycles (83%). Not unexpectedly the more sophisticated product groups such as Audio and AV/Photo, covering TVs, Digital cameras and TVs and the Computing, IT and mobiles category show declining repair success rates of 51% and 37% respectively.

General product catergory	Completed repair success rate % (category average)
Clothing & textiles	88.7
Bicycles	83.2
Tools (non elec.)	78.4
Jewellery	77.8
Garden & DIY power tools	70.1
Furniture	68.7
Household appliances	61.9
Other household	61.8
Audio and AV/Photo	51.3
Computing, IT and mobiles	36.9
ALL Products	66.7

Note: Figures based on 2165 repairs outcomes - once unclear outcomes removed from analysis.

Table 5.3. Completed repair success rates by product category

When Bicycles are removed from the analysis[38] the overall competed repair percentage drops[39] to 65% A complete list of product type repair success rates by descending order is provided in Appendix P.

[38] For an explanation as to why bicycles should be excluded see Section 5.3.3

[39] This percentage is provided here as it is needed later in the analysis.

5.2.1 Post repair reported failure rate

Questionnaire respondents who had reported a successful repair (129) were asked: '*What happened to their product post repair*'? 91.5% were still actively using the product with 3.1% reporting that the product had subsequently failed. 2.3% of visitors kept the product as a spare and 2.3% donated it to a charity shop (see Figure 5.4). This failure rate is surprisingly low, and possibly due to the majority (59.7%) of repairs reported having been completed within the last 6 months.

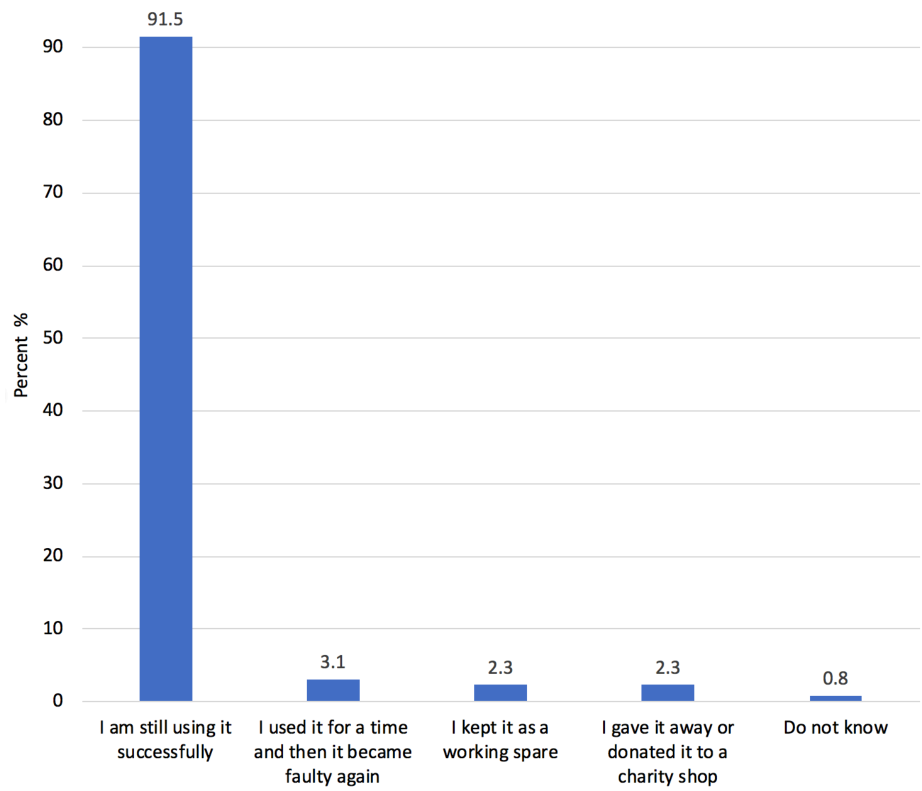

Figure 5.4 What happens to products after a successful repair (n=129)

5.3 Calculating the potential mitigation of GHGs from completed repairs

Two areas for the potential mitigation of GHG emissions resulting from successful repair are now considered:

a) Displacement of New Replacement Products (with their embodied GHGs for manufacturing and transportation) for all completed repairs, see equation-6.

b) Displacement of faulty products from Landfill waste (with their transportation and decomposition related GHG emissions) for all completed repairs, also see equation-6.

The calculation steps in determining the potential mitigation of GHGs are now described below:

5.3.1 Calculation of average Repair Café product weights

In order to provide representative weight data needed to calculate the embodied GHGs for each product type repaired[40], Repair Café datasets containing actual product weight data were analyzed. Weight data found for 606 products was used to determine the average product weight for each of the most commonly repaired products (Table 5.4).

No.	Item	Weight Min (kg)	Weight Max (kg)	Average weight (kg)	Sample number (n)
1	Bicycle pedal (non elec)	6.00	20.00	15.09	27
2	DAB/FM portable radio	0.25	4.50	1.61	44
3	Trousers	0.10	1.80	0.53	28
4	Table lamp (metal)	0.35	10.00	2.52	36
5	Laptop	1.00	3.50	2.49	10
6	Vacuum cleaner	1.60	10.70	6.28	32
7	Jewellery (necklace)	0.01	0.12	0.05	3
8	Sewing machine	4.00	15.00	8.62	35
9	CD/DVD player	1.20	6.00	2.77	14
10	Toaster (elec.)	1.60	3.90	2.29	13
11	Food mixer/blender (elec.)	0.85	9.50	4.04	8
12	Chair (mixed materials)	2.00	18.00	7.62	19
13	Toy (electronic/plastic)	0.10	4.60	0.81	16
14	Kettle (elec.)	0.80	1.60	1.04	7
15	Hedge trimmer (elec.)	2.00	10.50	4.08	16
16	Iron (steam)	0.80	1.60	1.20	9
17	Clock (electronic)	0.10	3.90	1.26	7
18	Torch (battery)	0.35	0.50	0.46	4
19	Shirt	0.06	0.50	0.25	5
20	Mower (electrical)	6.50	18.00	10.17	11

Table 5.4 Average weights for top 20 most commonly seen products

[40] This provides the figure for GHGs displaced if a New Replacement Product is not purchased as a result of a completed product repair.

An average of 8 recorded weight samples per product type were available from the data. Where less than 3 actual weights were available, online weight data was used to provide a minimum of 3 weight samples per product. Shown are the minimum, maximum and average recorded weights for the top 20 common product types seen (see Appendix Q for complete list). Bicycles were found to have the highest average weight (15kg) followed by Mowers (10kg). Once product weights were determined it was necessary to determine the GHGs embodied per kg for each of the repaired product types.

5.3.2 Calculating embodied GHGs for the 79 commonly repaired product types

For each product type, online journal and database searches were made for LCA studies reporting embodied GHGs ($kgCO_2e$) for a given product and weight[41]. Embodied GHG figures used from LCA studies included material, manufacturing and transportation related GHG emissions. No allowance is made for any use phase energy consumption since this is not within the boundary of the study[42]. Where possible embodied GHG figures from 3 studies have been averaged for each product type.

Suitable LCA studies, and manufacturer data such as an Environmental Product Declarations, were only identified for 53 of the 79 most commonly seen repair items. Therefore, where a suitable LCA derived figure for GHGs ($kgCO_2e/kg$) was not available from a published study, Granta CES EcoAudit 2017[43] was used to estimate embodied GHGs (kgCO2e/kg) for each missing product. These figures were calculated within EcoAudit by compiling individual Bills of Materials (see Appendix R for examples) using average product weights established from the Repair Café data. Transportation related GHG estimates are based on products being shipped by sea from China (Shenzhen) to UK (Southampton), via a recognized shipping route (15,467km), and transported by road freight (187km) to a central England distribution center for delivery by van to a UK address within 77km miles of a distribution centre.

Using equation-5, the 20 products with the highest calculated embodied GHGs are shown in Table 5.5, (see Appendix S for complete list).

[41] This method assumes that the embodied GHGs are directly related to the weight of product.

[42] It is assumed in this study that replacement items such as hedge trimmers (electricity use) and clothing (washing) will have the same in-use phase energy requirements as the products being repaired.

[43] EcoAudit 2017 uses a variety of sources including; ecoinvent, Plastics Europe Eco-profiles and the University of Bath 'Inventory of Carbon & Energy' (ICE) see: https://www.grantadesign.com/news/news/2014/ecoinvent.shtml

Rank	Product	Average product weight (kg)	Average embodied GHGs (kgCO2e/kg) for product type	Product embodied GHGs (kgCO2e)
1	Laptop	2.5	122.2	304.2
2	Tablet (iPad)	0.7	392.4	287.8
3	Hi-Fi music system	6.9	27.0	186.5
4	Speakers	6.3	27.0	169.2
5	Bicycle pedal (non elec)	15.1	9.9	149.6
6	VCR cassette recorder	4.7	27.0	127.8
7	Microwave oven	9.8	13.0	127.4
8	Hi-Fi amplifier	4.5	27.0	121.5
9	Phone (DEC)	1.3	76.9	102.6
10	Dehumidifier	7.6	10.4	79.1
11	CD/DVD player	2.8	27.0	74.8
12	Food mixer/blender (elec.)	4.0	15.7	63.6
13	Curtains	2.9	20.7	60.3
14	Shredder (paper)	3.8	15.7	59.5
15	TV (LCD)	3.3	17.4	56.8
16	Camera (digital)	0.5	119.7	55.8
17	Clothes steamer	6.1	9.1	55.3
18	DAB/FM portable radio	1.6	27.0	43.4
19	Mower (electrical)	10.2	4.0	41.0
20	Blanket (quilt/duvet)	1.5	27.5	40.8

Table 5.5 Embodied GHGs of products in descending order

Electronic products such as Laptops (304 $kgCO_2e$) and Tablets (288 $kgCO_2e$) were found to have the highest embodied GHGs. Smartphones were found to have the second highest embodied GHGs per kg, but their relatively low weight results in their average embodied GHGs being 39 $kgCO_2e$. LCA study, manufacturer declarations and EcoAudit calculated embodied GHG estimates for each product type are detailed together with a full list of referenced sources in Appendix K.

Once individual embodied GHG estimates for each product type had been established it was possible to estimate the total embodied GHGs for all completed repairs, as defined in Section 5.3 (a) and described below.

5.3.3 Total embodied GHGs for completed repairs

For each product type repaired, the number of completed repairs was multiplied by the product's embodied GHGs to find the total GHGs for each product type. Total embodied GHG emissions of 63,168 $kgCO_2e$ were embodied in all the product types for 1445 completed repairs (see Table 5.6).

Rank	Product	Average product weight (kg)	Average embodied GHGs (kgCO2e/kg) for product type	Product GHGs (kgCO2e)	Number of repairs completed	Total embodied GHGs (kgCO2e) for all repairs
1	Bicycle pedal (non elec)	15.09	9.91	149.6	129	19,293
2	Laptop	2.49	122.20	304.2	28	8,516
3	DAB/FM portable radio	1.61	27.00	43.4	82	3,556
4	Hi-Fi music system	6.91	27.00	186.5	12	2,238
5	Vacuum cleaner	6.28	5.89	37.0	60	2,218
6	Tablet (iPad)	0.73	392.41	287.8	7	2,014
7	Trousers	0.53	32.87	17.3	109	1,882
8	CD/DVD player	2.77	27.00	74.8	24	1,796
9	Sewing machine	8.62	4.06	35.0	49	1,714
10	Food mixer/blender (elec.)	4.04	15.74	63.6	24	1,527
11	Table lamp (metal)	2.52	6.96	17.6	84	1,476
12	Hi-Fi amplifier	4.50	27.00	121.5	10	1,215
13	Hedge trimmer (elec.)	4.08	9.35	38.1	30	1,144
14	Microwave oven	9.77	13.04	127.4	8	1,019
15	Mower (electrical)	10.17	4.03	41.0	20	821
16	Phone (DEC)	1.33	76.92	102.6	8	821
17	Speakers	6.27	27.00	169.2	4	677
18	Curtains	2.92	20.66	60.3	11	663
19	Chair (mixed materials)	7.62	2.13	16.2	34	551
20	VCR cassette recorder	4.73	27.00	127.8	4	511
21	Jacket (cloth)	0.81	28.28	22.8	22	502
22	Coat	0.78	26.90	20.9	23	481
23	Handbag	0.65	29.40	19.1	22	420
24	Drill (elec.)	1.69	15.74	26.7	15	400
25	Kettle (elec.)	1.04	31.06	32.3	12	388
26	Tape/cassette recorder	1.40	27.00	37.8	10	378
27	Bag (cloth)	0.58	29.40	17.1	20	342
28	Clock (electronic)	1.26	10.19	12.8	23	294
29	Dress	0.79	17.55	13.9	20	277
30	Printer	2.81	10.96	30.8	9	277
31	Toaster (elec.)	2.29	4.63	10.6	26	276
32	Smart phone	0.13	296.03	38.6	7	270
33	Jumper	0.37	30.48	11.1	22	245
34	Shredder (paper)	3.78	15.74	59.5	4	238
35	Necklace	0.05	70.00	3.5	68	238
36	Rucksack	0.79	21.09	16.6	14	232
37	Clothes steamer	6.08	9.09	55.3	4	221
38	Skirt	0.48	24.90	12.0	18	216
39	Camera (modern 35mm)	0.56	63.40	35.7	6	214
40	Lighting (decorative)	0.90	17.83	16.0	13	207
41	Standard lamp	4.44	3.85	17.1	12	205
42	Razor (elec.)	0.63	38.03	23.8	8	191
43	Toy (electronic/plastic)	0.81	7.06	5.8	31	178
44	Cardigan	0.41	38.25	15.7	11	172
45	TV (LCD)	3.27	17.37	56.8	3	170
46	Table (wood/metal)	6.30	2.19	13.8	12	166
47	Iron (steam)	1.20	9.09	11.0	15	164
48	Blanket (quilt/duvet)	1.48	27.53	40.8	4	163
49	Shirt	0.25	25.60	6.4	25	159
50	Dehumidifier	7.60	10.40	79.1	2	158
51	Fan (elec.)	1.38	11.33	15.6	9	140
52	Toy (soft)	0.54	30.97	16.8	8	135
53	Electric heater/radiator	3.28	2.92	9.6	13	124
54	Coffee machine (elec.)	1.93	9.06	17.5	7	123
55	Anglepoise Lamp	3.44	7.57	26.0	4	104
56	Shoes	0.66	21.34	14.1	7	99
57	Pressure washer (elec.)	5.55	5.90	32.7	3	98
58	Table lamp (wood)	2.38	3.89	9.2	9	83
59	Suitcase	4.13	4.84	20.0	4	80
60	Hair straightener/tongs	1.08	8.99	9.7	8	78
61	Hairdryer	0.64	8.99	5.8	13	75
62	Camera (digital)	0.47	119.67	55.8	1	56
63	Watch (battery)	0.17	23.34	3.9	12	46
64	Torch (battery)	0.46	5.29	2.4	18	44
65	Musical instrument (wood)	1.78	3.92	7.0	6	42
66	Extension cable	0.63	5.92	3.7	9	34
67	Shears	1.08	4.99	5.4	6	32
68	Loppers	1.18	6.85	8.1	4	32
69	Clock (mechanical)	2.00	3.97	7.9	4	32
70	Vacuum cleaner (battery)	1.92	5.27	10.1	3	30
71	Spade/fork (non powered)	1.32	4.46	5.9	5	29
72	Brooch	0.10	18.10	1.7	15	26
73	Headphones (over-ear)	0.43	7.08	3.0	8	24
74	Staple gun	0.76	5.42	4.1	5	21
75	Bracelet	0.08	18.10	1.4	14	20
76	Ornament (china/glass)	1.09	3.00	3.3	6	20
77	Secateurs	0.60	3.19	1.9	9	17
78	Earrings (metal)	0.01	97.27	1.3	12	16
79	Glasses (specticals)	0.27	7.10	1.9	5	9
	Totals (for all products)				1,445.0	**63,168**
			Excluding Bicycles		**1,316.0**	**43,874**
	Embodied GHGs (kgCO2e) per one completed product repair				Inc. Bicycles	**43.7**
					Ex. Bicycles	**33.3**

Table 5.6 Completed product repairs showing embodied GHGs for each product type

Bicycles represent the largest total of embodied GHGs at 19,293 $kgCO_2e$, followed by Laptops at 8,516 $kgCO_2e$. The average embodied GHGs across all completed repairs was 44 $kgCO_2e$.

For bicycles it is considered *unrealistic* to assume that if a bicycle had not been successfully repaired at a Repair Café, it would necessarily have been disposed of and replaced with a newly manufactured item. Cycling in the UK has undergone a revival (Grous, A., 2010), and with it an increase in the availability of commercial repair and cost-effective community refurbishing and re-use schemes such as 'we are cycling uk' (Williams, 2013). This has been further supported by the Department for Transport's £1.2 billion investment plan in cycling and walking published in 2017. This includes support for bicycle repair and maintenance, as acknowledged by Paul Tuohy of Cycling UK:

"Cycling UK's big bike revival will help tens of thousands of people back into cycling by getting your bikes checked over, fixed up and back into use. We are grateful to the Department for Transport for supporting this initiative, our third year of national activities" (Gov.uk, 2017b, p.1)

For other household products the disposal and new replacement scenario is considered far more likely (and supported by questionnaire responses, see Section 5.5). Therefore, to provide a more representative figure for average product embodied GHGs, figures are provided that exclude bicycles.

When excluding bicycles, total GHG emissions of 43,874 $kgCO_2e$ are estimated to be embodied in the products of 1,316 completed product repairs. This figure represents the total potential amount of GHGs that could be mitigated[44] via the displacement of new product purchases. For completed repairs excluding bicycles the average embodied GHGs are 33 $kgCO_2e$ per product repaired.

Looking at the general product categories, it can be seen that the greatest embodied GHGs are contained within the electrical and electronic equipment (EEE) products repaired as shown in Figure 5.5. In particular Computing, IT and mobiles.

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[44] Note The mitigation of GHG emissions only occurs if following repair the product continues to be used beyond the 'payback' period and a replacement product is not purchased.

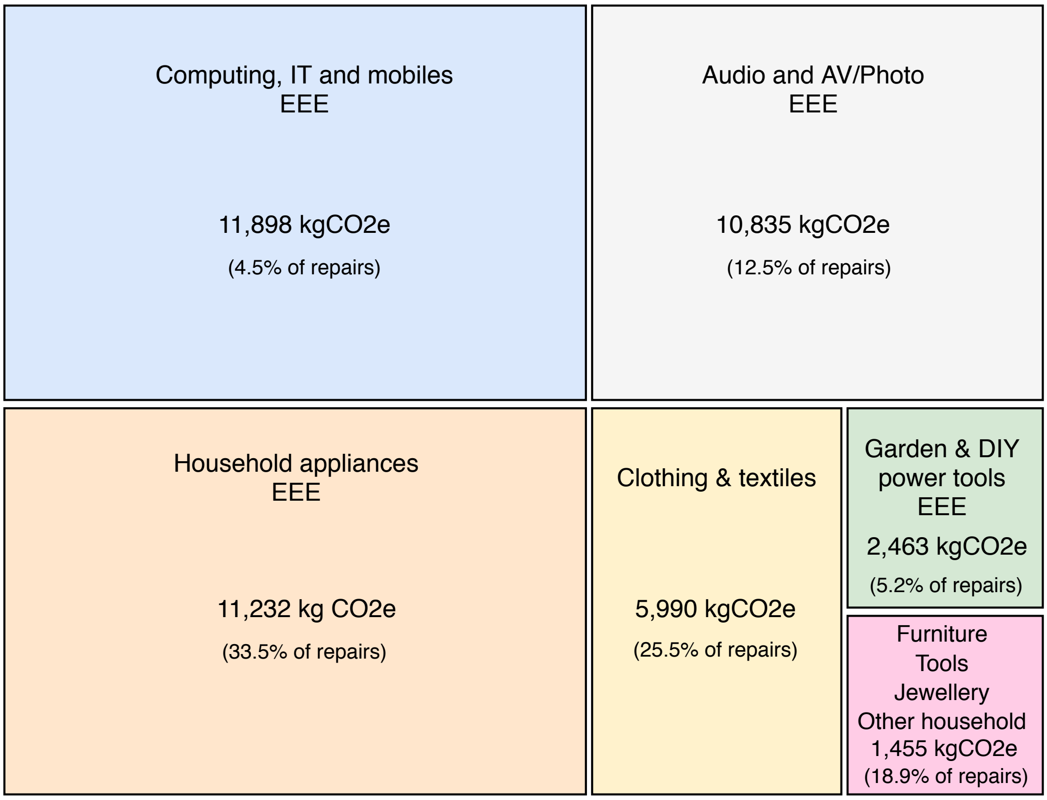

Figure 5.5 Product categories showing completed totals for embodied GHGs that are potentially displaced by avoiding purchase of new products

The results show that although the Computing, IT and mobiles category only account for 4.5% of successful repairs, product repairs undertaken in this category offer the highest possibility to mitigate GHG emissions, when considering that 27% or 12,000 kgCO_2e of the total embodied GHG emissions (44,000 kgCO_2e) resulted from the successful repair of just 59 products.

5.3.4 Landfill GHGs displaced using Defra based waste emission figures

Defra emission figures (Defra, 2017) for different domestic waste types were used to provide an estimate of displaced landfill and recycling[45] GHG emissions. This occurs when household products are prevented from entering landfill or recycling operations as a result of repair.

The Defra GHG emission figures for each waste type have been multiplied by the weight of completed product repairs for each waste category. This shows that textiles offer the largest

[45] Defra waste accounting practice only includes transport related GHG kgCO2e emissions for recycling, see (Defra, 2017)

potential for landfill GHG mitigation 98 kgCO_2e (see Figure 5.6) from a total of 1,316 completed repairs weighing a total of 3,109 kg.

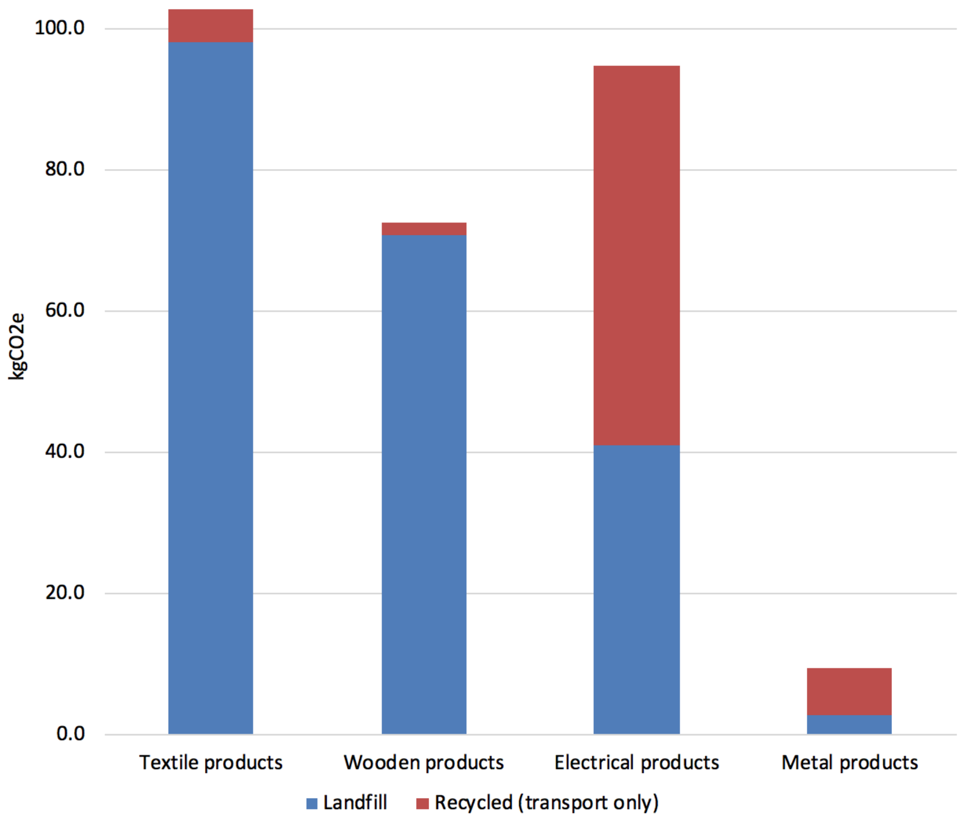

Figure 5.6 Total landfill and recycled GHG displacement for completed product repairs

If waste is allocated at 54.8% to landfill and 45.2% to recycled, as is typical for UK domestic waste[46], the total GHG emissions from waste diversion is estimated at just 117 kgCO_2e for all completed repairs. This gives an average landfill GHG saving of 89 grams CO_2e per completed repair (see Appendix T for complete listing).

It should be noted that since Defra waste recycling figures only account for transportation related GHG emissions, overall GHGs displaced by waste diversion are likely to be higher than shown. This is due to recycled materials reducing the use of virgin material in new products and thereby reducing GHG emissions.

[46] Based on published UK domestic recycling rates, see Defra, (2018)

5.4 Repair Café activity related GHG emissions

Consideration is now given to Repair Café activities that create additional GHG emissions. These emissions need to be subtracted from the total potential GHGs emission reductions from displaced new product manufacture and landfill waste (calculated in the previous sections).

Two GHG creating activities (see equation-7) are:

a) Usage of spare parts for repair (transportation and embodied GHGs).
b) Transportation of products and visitors to and from Repair Cafes (embodied vehicle and fuel related GHG emissions).

5.4.1 Product repair types and spare parts usage

Product repairs were divided into 43 categories and the embodied GHGs of spare parts typically used for each repair category calculated using EcoAudit, see Table 5.7.

Repair type	Repair and type of replacement part/s	Repair spare part embodied GHGs (kgCO2e)	Notes and assumptions
1	LCD screen replacement	3.96	
2	Software reset/reconfiguration	No parts needed	
3	Small lectrical connection repaired	0.21	
4	Product set-up required	No parts needed	
5	Cleaning/removal of debris	No parts needed	
6	Discrete electronic component	0.39	Average for basket of discrete components
7	Mechanical switch	0.21	AC mains type
8	Soldered repair	Insignificant	No sigificant use of materials or energy
9	Clasp or catch (jewellery) replaced	0.12	Assumes stock held by Repair Café volunteer (no packaging)
10	Metal part (Jewellery)	0.28	Includes packaging
11	Electrical motor bushes	0.17	Dyson DC07
12	Drive belt replaced	0.53	Nylon belt 40 grams
13	Mains cable repair	Insignificant	No sigificant use of materials or energy
14	Motor	4.83	Includes packaging
15	Battery replaced	0.37	Bassed on changing 3 x Alkaline AA batteries
16	Filter (air) replaced	0.78	Based on Miele air filter @ 0.153 kg
17	Low voltage cable repaired	Insignificant	No sigificant use of materials or energy
18	Aerial replaced	0.67	
19	Power supply - external	5.56	
20	Power supply - internal	5.53	
21	Fuse replaced	0.39	As per discrete electronic component
22	Electrical connector - including mains plug	0.57	
23	Mains cable replaced	3.30	Assumes 0.45 kg IEC mains lead 3m
24	Heating element replaced	2.16	Assumes kettle element 181 grams
25	Glued/screwed	0.06	Assumes 2 screws as per small fixing used
26	Eyelet replaced	0.01	Assumes Repair café holds spares (no packaging)
27	Gear wheel replacement	0.19	Assumes 20g metal part
28	ZIP replacement	0.35	Assumes large plastic zipper 15g plus packaging etc.
29	Bulb replacement	0.28	Osram incandescent kg CO2e plus packaging
30	New plastic part <= 10grams	0.24	Includes packaging
31	Button replaced (clothing)	0.08	Assumes Repair café holds spares (no packaging)
32	Patch and stich	0.08	Cotton denim patch at 250 grams per sq metre
33	Handbag clasp replaced	0.27	
34	Re-stiching required	Insignificant	No sigificant use of materials or energy
35	Unknown	N/A	
36	Puncture repaired	Insignificant	No sigificant use of materials or energy
37	Bicycle wheel spoke replaced	0.27	As per metal part calculation
38	Lubrication (grease/oil)	Insignificant	No sigificant use of materials or energy
39	Small fixing required (nut/bolt)	0.03	Assumes stock held by Repair Café M6 x 18 stainless steel
40	Metal part (small 10 grams)	0.27	
41	New electronic module or PCB	0.96	
42	Light bulb holder replaced	0.19	Includes packaging
43	Spare part not used	N/A	

Table 5.7 Typical product repairs and embodied GHGs of spare parts used

An analysis of 1014 repairs (for which detailed repair information was available), revealed that 52% of all attempted repairs required the use of no spare parts (see Appendix U). The most common repair undertaken was the ‘re-stitching’ of clothing and textiles (28% when patching included) followed by the repair of faulty ‘electrical connections’ (14%). The 15 most common repairs undertaken are shown in Figure 5.7.

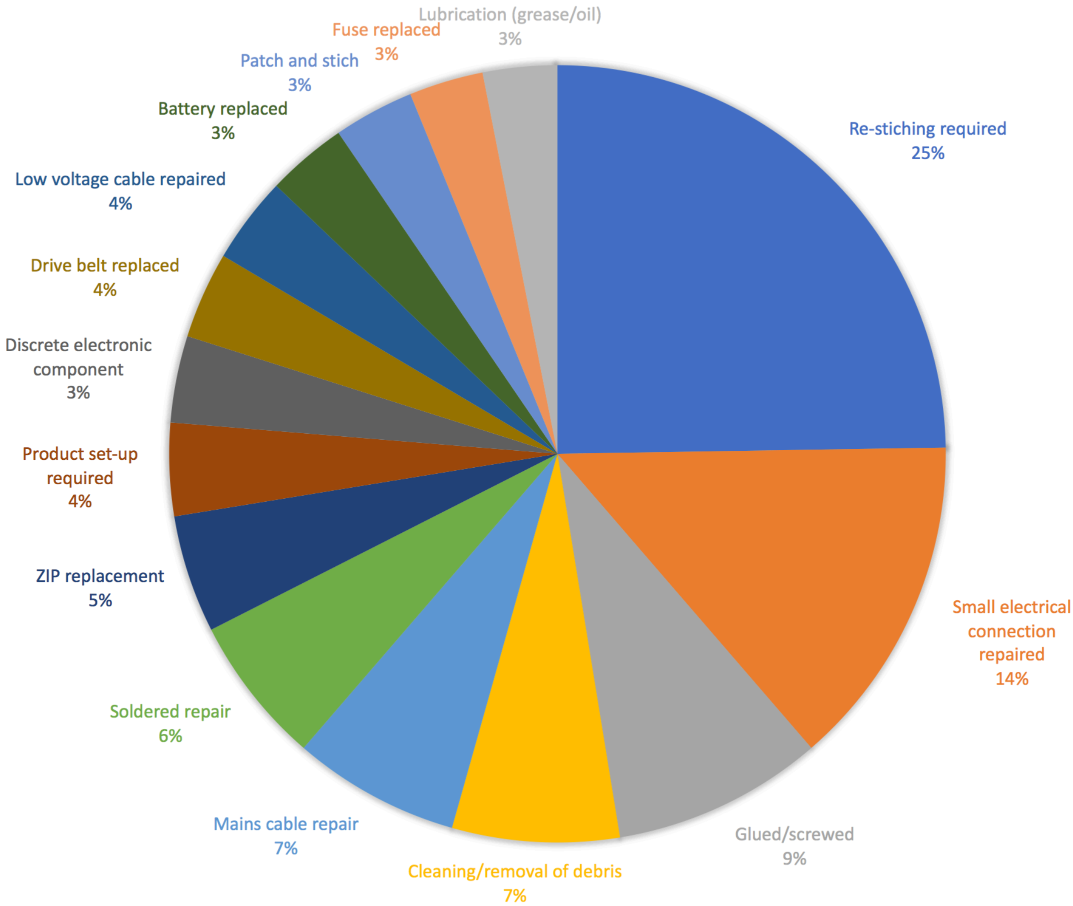

Figure 5.7 Breakdown of most common repair faults where repair details recoded

What is interesting is that 17% of all repairs could be classified as not being directly due to product failure, but an issue of general product maintenance, such as; cleaning/debris removal, battery replacement, lubrication and product set-up issues.

Looking specifically at the embodied GHGs contained within the spare parts used for product repairs, showed that for 74% of all attempted repairs no significant carbon (<10 grams $kgCO_2e$) was embodied within the spare parts used for repair (see Figure 5.8). For 1014 attempted repairs, spare parts accounted for embodied GHGs of 131 $kgCO_2e$ giving an average of 0.2 $kgCO_2e$ per repair for 675 completed repairs (see Appendix V).

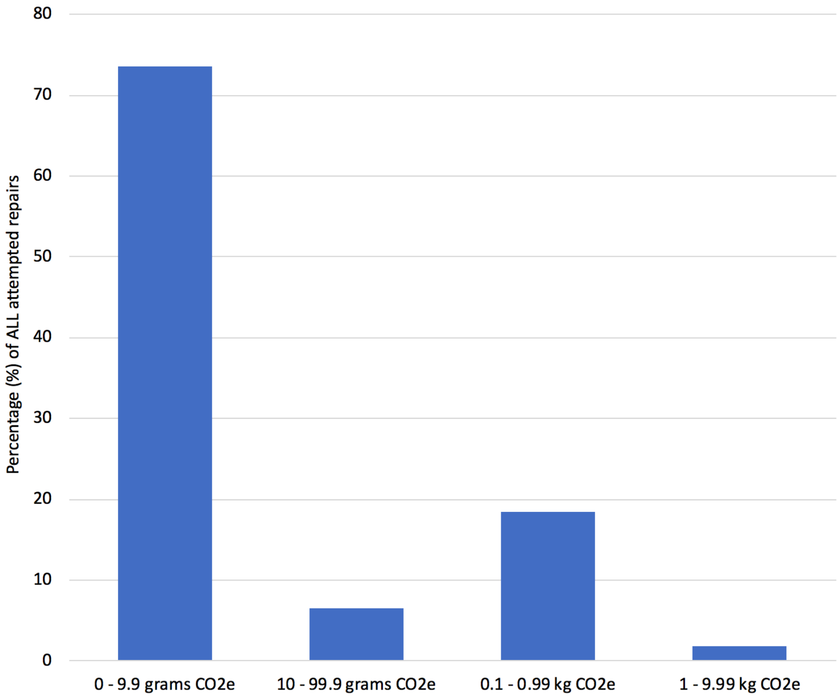

Figure 5.8 Range of embodied GHGs within spare parts used (per repair)

5.4.2 Transportation – visitor and volunteer related GHG emissions

Using the 222 feedback responses from the questionnaire, the majority (69%) of visitors and volunteers travelled to and from Repair Cafés used cars (Figure 5.9). Walking and cycling accounted for 28% of the overall transportation mix.

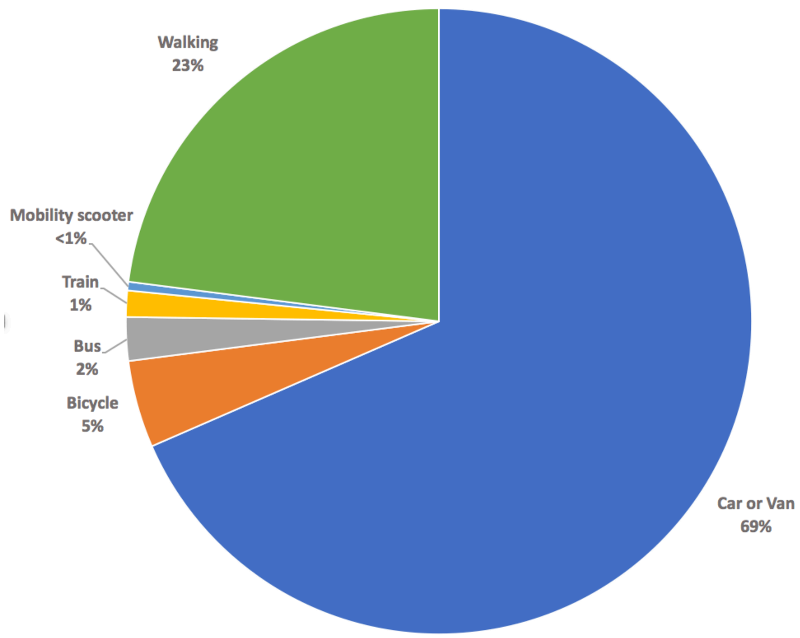

Figure 5.9 Modes of transportation used

The total distance travelled by 222 visitors and volunteers was 2,100 km giving an average 9.5 km return journey distance per visit. The average return journey distance by car was 11.5 km.

The majority (67%) of visitors and volunteers took a single product for repair at the last session attended, with 33% taking 2 or more products, giving an average number of 1.4 products taken per Repair Café visit. There was no statistical significance between the number of products being taken by volunteers and visitors (t-test Sig. 2-tailed = 0.595, see Appendix W). Volunteers therefore appear to form an important conduit for the transportation of product repairs to and from Repair Cafés.

A breakdown of transport related GHG emissions for 222 Repair Café visits by transport mode and fuel type used is shown in Figure 5.10.

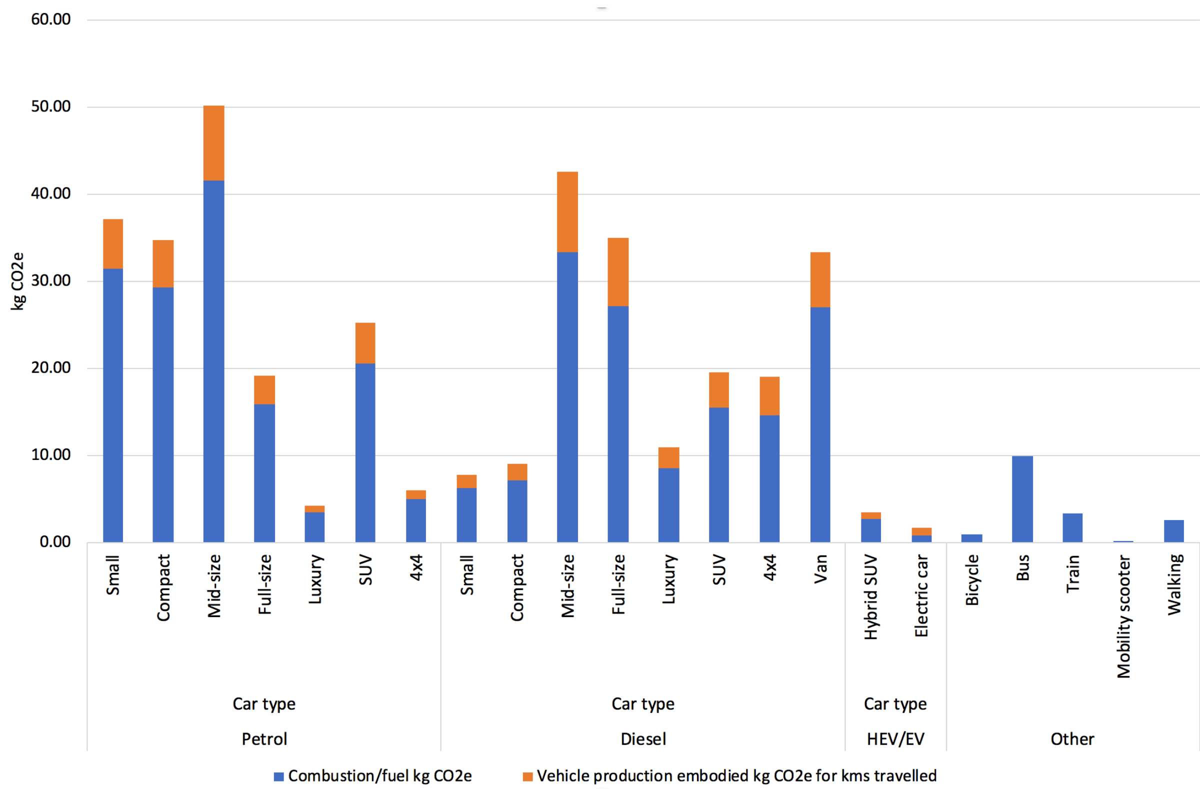

Figure 5.10 Transport related GHG emissions by vehicle type (for 222 return journeys)

Mid-sized petrol cars were responsible for the highest overall emissions of 50 $kgCO_2e$. The embodied GHGs for vehicles are accounted for and proportioned to the journey distance and expected vehicle lifetime (see Appendix X). Total transport related emissions were 307 $kgCO_2e$ from combustion and 69 $kgCO_2e$ for embodied GHGs, (these figures are used in equation-7). Diesel van GHG emissions for 3 return journeys were nearly identical to those of 18 return journeys using compact petrol cars. This was due to the greater recorded travel distance for van use. Appendix X provides a full breakdown.

Overall, transport related emissions are estimated at 1.7 $kgCO_2e$ per visit or 1.2 $kgCO_2e$ per repair when considering that 1.4 products are typically taken for each Repair Café visit.

5.5 Repair effect on displacement of new replacement product purchases

It cannot be assumed that product owners will necessarily be prevented from purchasing a new product. The displacement factor (Df) equation-3 takes this into account by including the probability (Pb) of the product owner not buying a new replacement product.

Questionnaire respondents who reported a successfully repaired product (129) were asked: '*if the repair had prevented the purchase of a new replacement product?*'

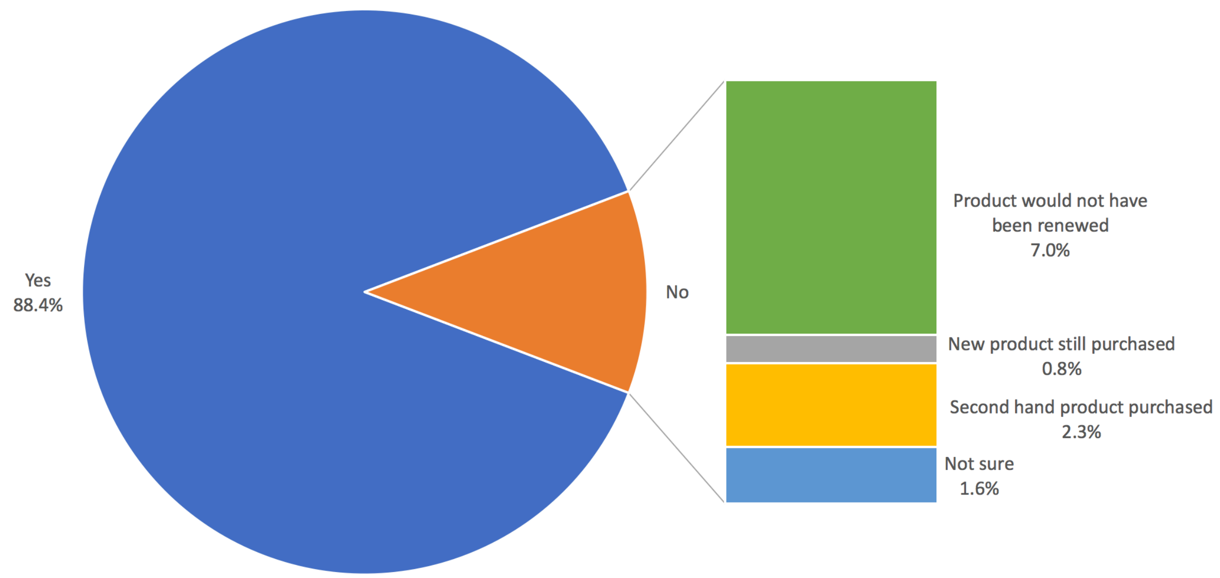

Figure 5.11 Did successful repair prevent new product purchase?

88.4% answered that the successful repair had prevented a new product being purchased, this figure includes respondents who subsequent experienced a product failure (3.1%) due to the questioning sequence. This is a significant finding since it is central to the premise that repair can displace the purchase of new products thereby mitigating GHG emissions. Of those that said 'No', only 0.8% reported buying a new replacement, 2.3% buying a second-hand item and 7% would not have replaced the item anyway (see Figure 5.11).

5.6 Consumption due to 'rebound effect'

Along with transportation and spare parts use, additional consumption due to increased spending (equation-7) was considered within the questionnaire. Questionnaire respondents (n=222) were asked: '*if they felt they had saved money as a result of visiting the Repair Café?.*' 87% (193) of the respondents felt they had or maybe had saved money (see Figure 5.12).

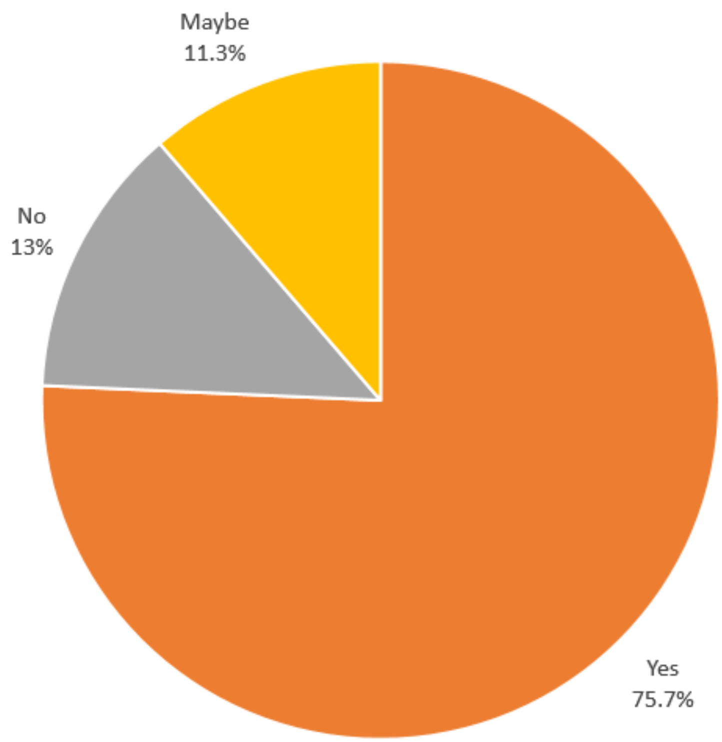

Figure 5.12 Perception of monetary savings after visiting Repair Café

When asked what they had spent this money on, the majority (42%) 'Did not know'. 14% 'Gave money to charity' and 10% 'Bought additional groceries' (see Table 5.8).

It is noteworthy that out of the 222 respondents there were 129 successful repairs reported (58%). However, 193 (87%) of the 222 respondents felt they had or maybe had saved money. Therefore, some visitors who did not experience a successfully completed repair still felt they had saved money. This finding was not anticipated and is included within the overall calculation of rebound related GHG emissions in the following Section 5.6.1.

Rebound spending category - Answer	Frequency	Percent
Do not know	93	41.9
Donated the money to charity	32	14.4
I bought some additional household groceries, wine etc.	22	9.9
Put the money into savings	20	9
Put money towards new purchase (phone, vacuum cleaner, shirt, dress etc.)	7	3.2
Treated myself or someone else to lunch or a meal out	5	2.3
No spare money - event helped restoration of unused item	5	2.3
Put the money into a holiday fund	4	1.8
Put the money towards a day out	2	0.9
Household bills	2	0.9
I bought a used item	1	0.5
Total	193	86.9

Table 5.8. Spending of money saved by visit to Repair Café

In practice it is acknowledged that nearly all types of additional spending (and saving) will increase economic activity and therefore GHG emissions. Charity donations, for example, may lead to the purchase of goods and services to support economic development in developing countries that result in negative environmental impacts (Everett et al., 2010).

5.6.1 Calculation of 'rebound' spending and GHG emissions

In order to make an estimation of the rebound effect from money saved by a visit to a Repair Café, the carbon emissions per £ re-spent were estimated using a typical basket of commodities and services consumed by UK households (ONS, 2017) see Table 5.9.

Commodity or service[2]	Weekly spend[2]	Weighted percentage[2]	GHG intensity (kgCO2e/£ spent)[3]	Resulting proportion of GHG (kgCO2e/£ spent)
Food and non-alcoholic drinks	56.8	12.5	1.23	0.153
Alcoholic drink, tobacco and narcotics	11.4	2.5	0.32	0.008
Clothing and footwear	23.5	5.2	0.38	0.020
Housing, fuel and power[1]	72.5	15.9	4.00	0.637
Household goods and services	35.5	7.8	0.58	0.045
Health	7.2	1.6	0.59	0.009
Transport	72.7	16.0	0.90	0.144
Communication	16.0	3.5	0.72	0.025
Recreation and culture	68.0	14.9	0.33	0.049
Education	7.0	1.5	0.29	0.004
Restaurants and hotels	45.1	9.9	0.60	0.059
Miscellaneous goods and services	39.7	8.7	0.90	0.079
Total	455.3	100.0		1.23

Notes 1 Proportioned 50% gas, 50% electricity. Note 2 Figures from ONS, (2017)

Note 3 Figures derived from https://www.carbonfootprint.com/calculator.aspx

Table 5.9 Spending and resulting GHG emissions per £ spent

The study assumes that all post-repair consumption falls into this basket. Therefore, each commodity or service is weighted based on the average weekly spend, and using the GHG intensity per £ for each, the resulting GHG emissions calculated. Rebound spending emissions were calculated to be 1.23 kgCO_2e/£ re-spent (Table 5.9).

The next step was to calculate the rebound effect in terms of GHG emissions per completed repair: This is calculated on the basis that the average number of items taken for repair is 1.4 per visit. For 222 visitor journeys the number of products checked in is 1.4 x 222 = 311. For 311 checked-in repairs and using the average repair rate of 65%[47], the number of completed repairs calculates as: 311 x 0.65 = 202.

Although the questionnaire did not ask directly how much money visitors felt they had saved, the average donation was found to be £3.72 per repair[48]. As noted 87% or 193 visitors (222 visitors x 0.87) felt they had saved or maybe saved money as a result of visiting the Repair Café. Using the average donation figure, GHGs due to rebound effect is estimated as 193 visitors spending £3.72 with carbon emissions of 1.23 kgCO_2e/£, equaling 883 kgCO_2e. For 202 completed repairs GHG emissions are therefore estimated at 4.4 kgCO2e per repair.

5.7 Net balance of GHG emissions per repair

Using equations 6, 7 and 8 developed in the methodology, a GHG emissions 'gains and losses' balance sheet is presented in Table 5.10. This shows the potentially displaced emissions resulting from all 1,316 completed repairs via the prevention of new product consumption and landfill waste (-43,991 kgCO_2e). Subtracted from this GHG saving is lost new product GHG displacement (5,103 kgCO_2e), using the calculated Displacement factor (0.884), as not all owners would have purchased a new replacement product. Further deductions from total GHG savings are the repair related GHG emissions (7,776 kgCO_2e) created by transportation, spare parts use and rebound spending that occurs as a result of all attempted repairs (column 3). This results in the potentially mitigation of -31,112 kgCO2e of GHG emissions.

[47] This repair rate figure is used rather than the (58%) since it is based on a much larger sample number.
[48] This figure is used in the absence of sufficient data on spending post repair. See Appendix Y.

Source of GHG emissions or dsplacement	GHGs displaced (kg CO_2e) (excluding bicycles)	GHGs emitted (kg CO_2e)	GHGs displaced for all repairs (kg CO_2e)	Percentage of new product embodied GHGs lost	Explanation notes
Prevented new product embodied GHGs from completed repair items	-43,874				Total for 'Ne' (see equation 6) for 1316 completed repairs
Landfill GHG displacement (repaired items)					
Landfill	-109				Total for 'Lf' wth allowance for
Recycled	-8				Recycling transportation (see equation 6)
Sub total	-43,991				
Displacement factor at (1-0.884)	5,103			-11.6	As determined from questionnaire
Total for potentially mitigated GHGs Pn	-38,888				Total for 'Pn' Potential (see equation 6) 1316 completed repairs 2010 products taken with 65% success rate (excluding bikes) This represents 2010/1.4 return jouneys on which to calculate transport emissions
Transportation for all items taken					
Fuel CO2 emissions		1,407		-3.2	Total for 'Tp' (see equation 7)
Enbodied GHGs in vehicle for kms travelled		316		-0.7	Total for 'Ve' (see equation 7)
Sub total (1)		1,723			Sum of Tp + Ve for all transportation or 1.2 kgCO2e per journey as per results
Spare parts for ALL attempted repairs		263		-0.6	Total for 'Sp' (see equation 7) at 0.2 kgCO2e/completed repair
Rebound consumption (commodities or services)		5,790		-13.2	Total for 'Rb' (see equation 7) at 4.4 kgCO2e/completed repair
Sub total (2)		6,053			Sum for Sp + Rb (see equation 7)
Total for Repair related GHG emissions **Re**		7,776			Total for 'Re' (see equation 7)
GHGs emittted per completed repair		5.9			
Pn-Re			-31,112		Total for Pn-Re (see equation 8)
				-29.3	1316 repairs
Total GHGs mitigated kg CO2e/repair **Pm**			**-23.6**		

Table 5.10 Calculation of potential GHG emissions saved for one completed repair

It is therefore possible to say that on average each completed repair potentially mitigates -24 kgCO_2e for the purpose of reporting GHG savings. This figure is for the average UK Repair Café profile of products repaired[49], and considers, displacement factor[50], completed repair rate, spare parts used, likely rebound spending, transportation type and distance travelled to and from a repair event.

Whilst the average -24 kgCO_2e/repair figure helps to provide a baseline from which to report GHG mitigation, it is important to estimate temporally when environmental GHG benefit starts to occur following a repair. An average saving of -24 kgCO2e/repair does not occur immediately after repair, since factors such as the product type's life expectancy period, and how long the product continues to be used following repair are critical. This is shown by equation-12 in Section 4.8.8, and now examined below.

[49] This figure excludes bicycles as discussed, if included the figure using the same methodology is -31 kgCO_2e per completed repair or -8.8 kgCO_2e/kg of product repaired.
[50] Note: Figure of -24 kgCO_2e uses repair life extension factor Rl = 1 for the calculation of displacement factor (equation-3). If Rl = 0.5 then GHG mitigated per repair would drop to 9 kgCO_2e.

5.8 Annualized embodied GHG emissions and calculating repair 'payback' period

If we consider a laptop with a life expectancy of 5 years (WRAP, 2017) and embodied GHG emissions of 304.2 $kgCO_2e$[51] we can say that amortized over each year of its life it will have been responsible for emissions of 304.2/5 = 60.8 $kgCO_2e$/year. If after 5 years it is repaired, and the repair related GHG emissions are 5.9 $kgCO_2e$ (see Table 5.10, column 3), then using equation-11 we can see that the laptop only has to continue to be used for period of 35 days to have 'paid-back' the repair related GHG emissions and start accumulating a net environmental benefit. The repair from that point will accumulate displacement savings of 60.8 $kgCO_2e$/year whilst the computer continues to work. If the computer was disposed of in less than 35 days, then it would have been more beneficial to have purchased a new computer as this would have avoided the additional repair related carbon emissions.

Using the average embodied GHG emissions of 33.3 $kgCO_2e$ (that of a typical kettle) for products repaired at Repair Cafés, Figure 5.13 shows how the payback period, after which benefit occurs, changes depending on the product's life expectancy.

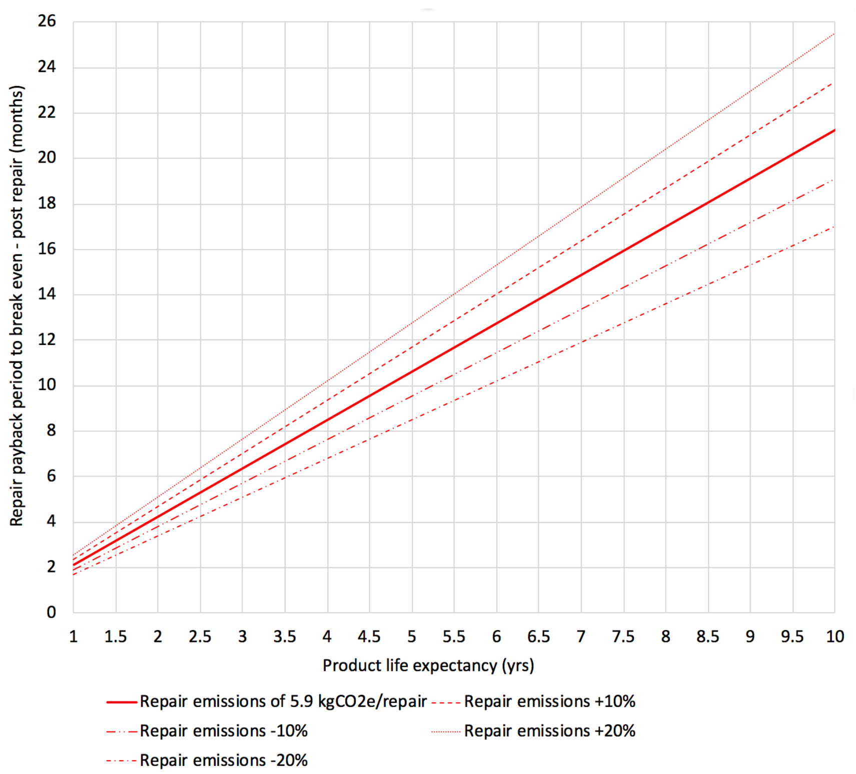

Figure 5.13 How repair 'payback' time (months) varies with product life expectancy (yrs)

[51] Disposal/landfill waste disposal GHG emissions are not included as they are insignificant compared to embodied GHG emissions.

This graph (using equation-13) assumes Repair Café related emissions of 5.9 kgCO_2e per repair (solid red-line). The sensitivity to change in repair related emissions is also shown (dashed-lines). This shows that the repair payback period is longer for the repaired product as the expected design life of its new replacement increases, or repair 'payback' period is proportional to the replacement product's life expectancy.

For comparison, payback periods are now examined for the general product categories. The range (with interquartile bar markers) of embodied GHGs for each product category are shown in the box and whisker chart (Figure 5.14). Products falling within high embodied emissions categories are more likely to have shorter payback times (equation-13).

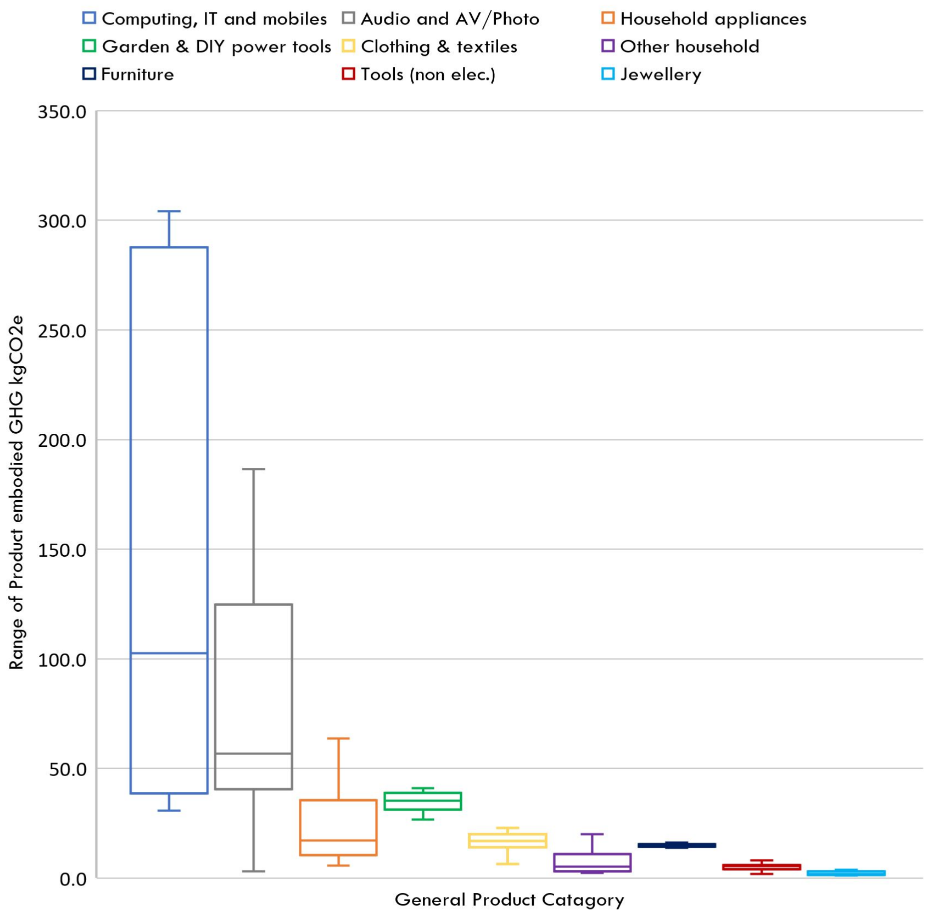

Figure 5.14. Range of embodied GHGs for different product categories

Using average product life expectancy and embodied GHGs, the payback period following repair has been calculated for each product category and is shown in Table 5.11.

General product catergory	Total embodied GHG (kgCO2e)	Total product weight (kg)	No of repairs	Category product average embodied GHGs (kgCO2e)	Average life expectancy (yrs)	Payback period following repair (yrs)	Life expectancy based upon reference
Computing, IT and mobiles	11,898	112	59	201.7	2.7	0.1	Cox et al., (2013)
Household appliances	11,232	1,581	441	25.5	5.5	1.3	Cox et al., (2013)
Audio and AV/Photo	10,835	401	164	66.1	7.0	0.6	Cox et al., (2013)
Clothing & textiles	5,990	220	336	17.8	3.3	1.1	WRAP, 2017
Garden & DIY power tools	2,463	368	68	36.2	5.5	0.9	Cox et al., (2013)
Furniture	717	335	46	15.6	10.0	3.8	Cox et al., (2013)
Jewellery	355	9	126	2.8	12.0	25.1	Estimate
Other household	251	56	47	5.3	5.5	6.1	Cox et al., (2013)
Tools (non elec.)	132	27	29	4.6	12.0	15.6	Estimate
ALL catagories (ex. Bicycles)	43,874	3,109	1,316	33.3	5.9	1.0	Weighted average
Bicycles	19,293	1,946	129	149.6	15.0	0.6	Levenberger et al., (2010)

Table 5.11 Typical 'payback' period for repairs falling into different product categories

This highlights a big difference between product categories and repair payback periods. Repairs of Computing, IT and mobiles have short payback times of just over 1 month before producing a net benefit. In contrast categories such as jewellery with low embedded GHG emissions and a long-life expectancy may fail to ever reach a point in time where the repair provides a net benefit with respect to GHG emissions. It also becomes evident that judgement is needed on whether taking an item for repair is worthwhile with respect to the payback period and how long any repair is likely to last. Not all repairs will necessarily mitigate GHG emissions. Also, of note is that the bulk weight of landfill diversion (>50%) comes from one product category, household appliances that have a close to average payback period.

Overall, mitigation of GHGs for the average completed repair at a UK Repair Café begins once the product continues to be used beyond a period of 12 months (1yr).

5.9 Sensitivity analysis

The sensitivity of potentially mitigated GHG emissions of -24 $kgCO_2e$ (average) for each completed product repair, calculated in Table 5.10, was then examined with respect to variance in the product's life extension period (Rl), and the value in (£) of any rebound spending (Ps) following a successful repair. The study result of potentially mitigated GHGs of -24 $kgCO_2e$ per completed repair is indicated on Figure 5.15.

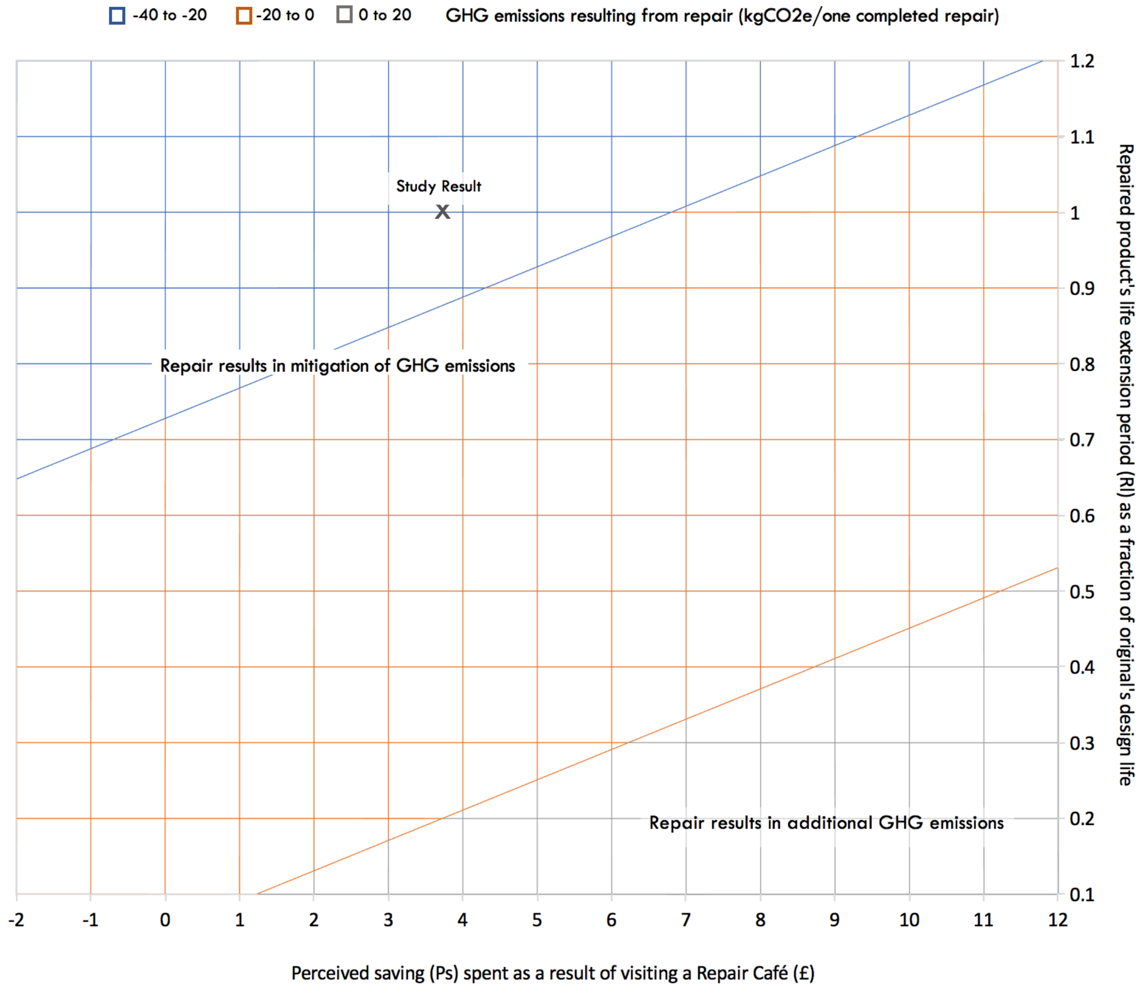

Figure 5.15 Sensitivity of mitigated GHG emissions to (Rl) and (Ps) from one completed repair

For the analysis, the graph area is divided into 3 bands for GHG emissions that result from a completed repair (using equation-8); grey (0 to 20kgCO_2e), orange (0 to -20kgCO_2e) and blue (-20 to -40kgCO_2e). The analysis in Figure 5.15 considers an average product with embodied GHG emissions of 33kgCO_2e, expected life of 5.9 years and a rebound spending carbon intensity of 1.2 kgCO_2e/£ re-spent (as described in the results).

As can be seen, when keeping rebound spending at £3.72, as the product's usable repaired life extension (Rl) period shortens, the level of potentially mitigated GHG emissions falls until becoming zero and turning positive (going into grey band) at 0.2. This equates to 0.2 x 5.9 years = 1.18 years. If we now consider the same average product repair where the owner spends £10 due to the 'free' repair, the product would need to be used beyond 2.6 years (0.45 x 5.9 years) for the repair to have resulted in a reduction of GHG emissions, and therefore provide a net benefit. This analysis highlights the need to avoid rebound spending and focus repairs towards those products that have high embodied GHG emissions, and relatively short life expectancies, if maximizing the reduction of GHG emissions is the prime objective. A table of the plotted data shown in Figure 5.15 is available in Appendix Z.

5.10 Trend in repair numbers at Repair Cafés

There is a weak positive trend (R^2=0.301) for the average number of products seen for repair at consecutive sessions across all Repair Cafés (Figure 5.16). (Repair Café data has only been included where the number sessions run was > 5). The average number of products taken for repair across all repair café sessions is estimated as 25 with a maximum of 75 and minimum of 2 products seen at an individual repair event.

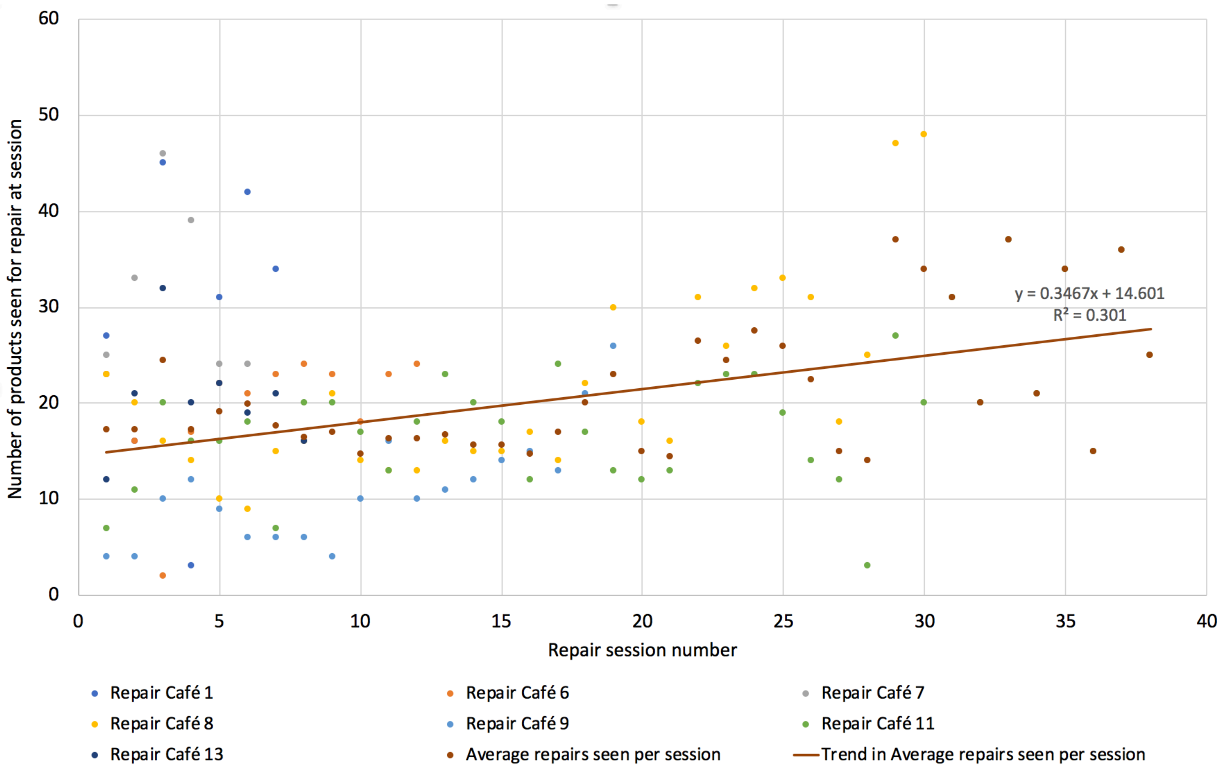

Figure 5.16 Trend in average number of products seen for repair

6 Discussion

6.1 Observations

In answer to the key question: 'Do Repair Café activities help mitigate greenhouse gas emissions and if so what order are these likely to be?'. The results indicate that for 1316 completed product repairs weighing 3,109 kg, Repair Cafés potentially mitigated a total of -44,000 $kgCO_2e$ in displaced new product embodied GHGs and landfill emissions. To this total needs to be added an estimated 8,000 kgCO2e of GHG emissions that occur as a result of direct and indirect activities associated with the Repair Cafés service. The outcome is a potential net GHG emissions saving of -31,000 kgCO2e (see Figure 6.1).

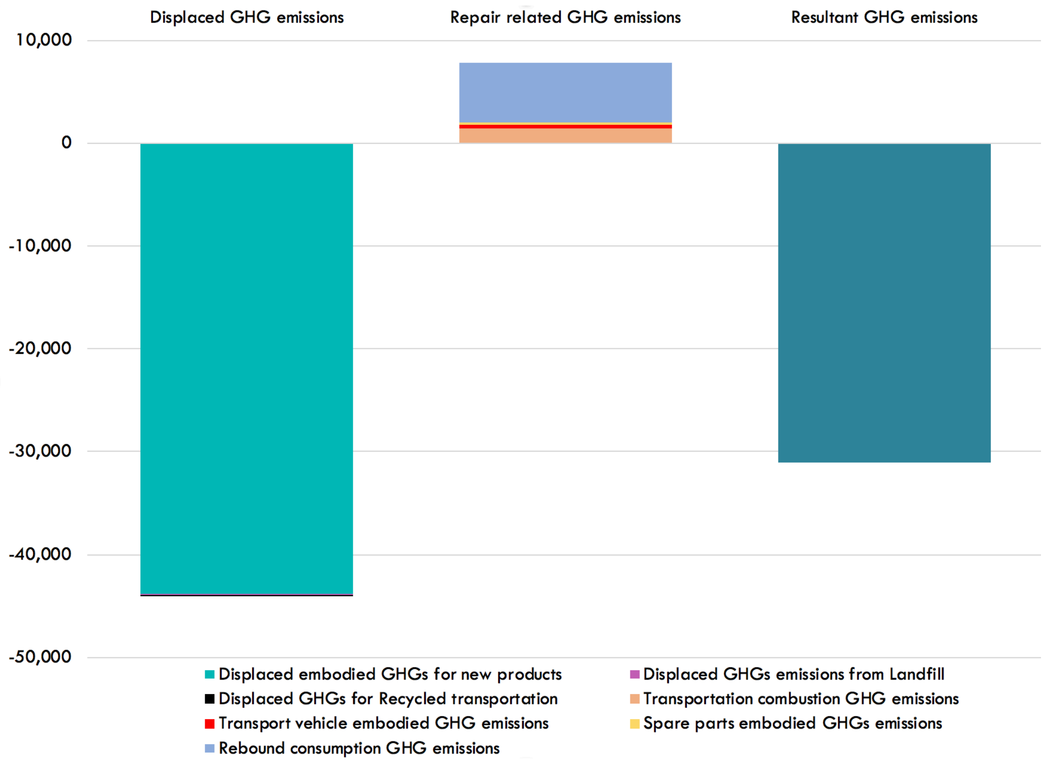

Figure 6.1 Total GHGs emissions displaced and created by 1316 completed repairs

Therefore, each completed repair potentially mitigated an average of -24 $kgCO_2e$ of GHG emissions or -10 $kgCO_2e$ for each kilogram of product repaired. For comparison the Repair Café Foundation in their reporting of GHG emission savings use a conversion figure of -1kgCO2e[52] per kg product repaired, and the Restart Project's 'Fixometer' reports an average of –21 $kgCO_2e$/kg.[53]

[52] See: https://repaircafe.org/en/200000kg-of-co2-emissions-saved/
[53] See: https://therestartproject.org/fixometer/

If we consider that in the UK, 10 kg per capita of household WEEE is taken for waste management each year (Eurostat, 2018) and that 37-70% (see Table 5.3) of products falling within the WEEE category could be relatively easily repaired, there is a significant opportunity to reduce GHG emissions by increasing household product repair. If just 1 kg of WEEE was repaired per capita, then based even on the average (-10 kgCO2e/kg) GHG estimate in this study, 650,000t kgCO2e of GHG emissions could be prevented. This is equivalent to the food related GHGs emissions for 143,000 UK households (Gough et al., 2011).

The analysis shows that mitigation of GHGs only starts to occur once the repair 'payback' time period is exceeded, and in the case of the average product this is approximately 12 months. From that point onwards, the mitigation of emissions accrues at the embodied GHG annualized rate for the product type repaired. The repair 'payback' period intuitively appears long for some product categories when considering the low use of spare parts. This is partly due to the methodology including GHG emissions for the associated transportation and spare parts use for those products that fail to be repaired but have consumed resources. It is also due to the embodied GHGs and life expectancy of products varying greatly across the categories of products seen at Repair Cafés. Products with low embodied GHGs and long-life expectancies require far longer time periods to recoup repair related GHG emissions. Adopting 'green lifestyle' principles such as travelling by train, cycling or walking where possible to visit a Repair Café, and reducing unnecessary 'rebound' spending post repair has a significant influence on increasing the rate at which a successful repair starts to mitigate GHG emissions. Taking multiple items for repair per visit would also further reduce 'payback' periods.

When considering that Repair Cafés repair a very wide range of products of different types, technologies, ages and brands, the average repair rate is surprisingly high (65-67%). This is possibly a reflection on the general high level of education and diversity of professional experience amongst volunteers (Charter and Keiller, 2016). The high completed repair rate and low reported use of manufacturer (and potentially costly) spare parts also indicates that many household products in the UK are being disposed of and replaced prematurely. This indicates that a significant barrier to repair is often the general experience and knowledge of householders to diagnose and rectify faults, rather than limited availability of manufacturer spares. This is further supported by 17% (1 in 6) of all product repairs not being due to a specific component failure but general product care and maintenance issues. Repair Cafés and similar organizations are therefore ideally positioned to help inform and encourage people to carry out simple maintenance and repair procedures at home. This would further amplify the benefits of repair and further reduce GHG emissions.

Not all product repair categories offer the same potential to mitigate GHG emissions. Where the embodied GHGs are low, often when the product weight is particularly low, such as for Jewellery, the GHG emissions created by transportation to the Repair Café and spare parts used may exceed those of a new product purchase. Should such products therefore be replaced rather than repaired? This demonstrates where making a sustainability impact decision based only on GHG emissions is too narrow, and wider consideration of further indicators, such as resource preservation, and gains in human welfare (social interaction and support) occurring at the point of repair, would offer a more complete assessment. In addition, the attachment that people can form with their possessions (Dewberry et al., 2016) and the benefits of maintaining and preserving those connections needs to be considered. This highlights the current 'social-factor' limitations of the CE concept and the danger of burden shifting between environmental and social sustainability (Korhonen et al., 2018). Repair Cafés are providing social as well as environmental benefits and this needs to be appreciated. Finding ways of assessing and reporting a range of sustainability indicators for community-based repair is therefore important.

The results show that products within the Computing/IT and Mobiles category contain significant embodied GHGs and are the largest contributor (27%) to potential GHG savings. However, this category has a relatively low repair success rate (37%) and accounts for a small percentage (4.5%) of completed repairs. Improving the reliability and repairability of products in this category could significantly increase further reductions in GHG emissions. Unfortunately, products within this category, such tablet computers, are more difficult to repair and have the shortest life expectancy. This is where strengthening and broadening the current regulatory instruments such as the Ecodesign Framework Directive[54] could help reduce the need for, and challenges to repair. With the need to slow resource consumption and increase material circularity within the economy, extending product life cycles by improving durability[55] and designing for disassembly (DfD), particularly within this product category, is urgently needed. This is something that the European Parliament has passed a resolution on but has yet to put into law[56]. There therefore exists a significant reason for Repair Cafés to both promote repairs of Computing/IT and Mobile devices and increase repair success rates in this area; possibly through the training or recruitment of more repairers with the necessary skills.

[54] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125
[55] Ideally by not increasing material consumption and the ability to re-use and recycle materials.
[56] EP has voted on a resolution. See: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2017-0214+0+DOC+XML+V0//EN

The findings from the sensitivity analysis highlight the need for judgement in whether a product's post repair likely life expectancy warrants the direct and indirect GHG emissions associated with its attempted repair. Keeping and using repaired products for as long as they remain serviceable, and not replacing prematurely, significantly increases the potential for reducing GHG emissions.[57] The low number of and level of embodied GHGs in the spare parts used, indicates that Repair Cafés operate very efficiently and do not directly contribute significantly to GHG emissions. Importantly they are not carrying a large inventory of spare parts with their associated embodied GHGs as a commercial operation would be expected to do[58]. However, as the sensitivity analysis shows, indirect GHG emissions from increases in spending due to the rebound effect are potentially more problematic. Along with the benefit of Repair Cafés repairing products for 'free', with little direct cost in expensive spare parts, comes the risk of additional spending on GHG intensive goods and services. Finding creative ways of diverting perceived savings away from such consumption could therefore appreciably help offset this danger. Promoting donations at the point of repair, towards supporting environmentally beneficial projects, or charging an entrance fee, could help reduce this rebound effect.

6.2 Limitations of study

The study uses a broad range of data sources, such as various LCA studies and EcoAudit carbon footprint assessments to calculate the embodied GHG emissions of household products. Although this is considered the most appropriate and accurate method of profiling embodied GHGs, since each product type is individually considered, there is inherently a wide variance in LCA estimates due to differences in the base assumptions used. To improve overall data quality, results from more than one study have been used. It should be noted that LCA derived embodied GHG emissions for specific product weights have been proportioned to average Repair Café product weights to calculate their embodied emissions. In practice this may not always be accurate, since factors other than material weight can affect the total embodied GHG emissions of a product.

The study assumes that Repair Cafés have reported repair outcomes using the same definitions. Only repairs reported as being 'completed or successful' have been considered in the overall GHG calculations, with no allowance being given to partially completed repairs,

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[57] This is assuming the a new replacement product is not significantly more energy efficient.
[58] See spare parts support issues at Fairphone: https://www.fairphone.com/en/2017/08/03/a-closer-look-at-the-spare-parts-supply-chain/

since they carry significant uncertainty about the final repair outcome. If partial repairs were included, then the net benefit of Repair Cafés with respect to the mitigation of GHG emissions could be higher than estimated.

Transportation GHG emissions assume that journeys are made purely for the purpose of visiting a Repair Café. In practice some return journeys will be taken for multiple purposes, such as shopping as well as visiting a Repair Café. This would reduce the level of transportation GHGs associated with each repair.

The study assumes that products are repaired once before replacement. In practice there is no reason why some products should not be repaired multiple times to further extend their life. This would enhance GHG emissions savings as product repair life-times are extended further deferring the need for a replacement product. The caveat is that repair related emissions, such as those embodied in spare parts, need to be kept low in relation to those of a replacement product, and the time interval between repairs kept sufficiently long.

The results as presented offer an insight that specifically reflects the UK Repair Café operating environment, owner-user behaviour and household product profile, and are therefore only relevant to this region. This will however allow a more complete ongoing assessment of UK Repair Café performance with respect to the prevention of GHG emissions in future[59].

There are two key areas where assumptions have been made and further research is needed:

Understanding how long repaired products continue to function and delay a new product purchase post repair, to validate that the potential GHG displacement estimated actually occurs. This requires a follow up study as there is currently insufficient data to determine how far repair extends the life of different household product types and delays their replacement over the longer-term.

The level of consumer spending following financial savings as a result of 'free' product repair, needs to be ascertained. Retail consumption as considered in terms of the 'rebound effect' assumes a relatively low value of spending and any increase could significantly alter the level of GHG emissions. It could be argued that the financial saving is significantly greater and rebound spending should be proportioned directly to the replacement cost of products successfully repaired. This approach is also valid and dependent upon the areas considered within the study boundary. For example, for the unsuccessful repairs where someone has

[59] The methodology presented could be extended for use in other countries.

incurred costs and no financial gain, will it decrease their spending capacity to consume more carbon intensive goods and services? Does the social contact stimulated by community repair offer longer term health benefits to volunteers and visitors that reduces future demand on health services? Answering such questions is beyond the scope of this study, but the methodology includes rebound spending as an important factor that should be adjusted accordingly as more accurate modeling and data become available.

6.3 Conclusions

On the basis of the data analyzed and methodology described, UK Repair Cafés offer a successful and efficient repair service to local communities, and in the process provide the potential to mitigate an average of -24 kgCO_2e of GHG emissions per completed repair. Direct and indirect GHG emissions are created as a result of the repair service, and these emissions need to be 'paid-back' by successfully extending the life of products past the break-even point (just over1 year) after which net GHG emission reductions begin to accumulate. Products must therefore continue to be used beyond this point in time for the potentially mitigated GHG emissions to be realized[60].

The product categories identified with the highest embodied GHG emissions are also those requiring the shortest post repair use period before reaching their 'payback' time, and therefore offer the greatest potential to mitigate GHG emissions. Focusing on improving repair success rates, by just a few percent of Computing/IT and Mobile products offers a significant opportunity for Repair Cafés to increase their effectiveness in decreasing GHG emissions even further.

The high level of repair success and prevention of new product purchases reported by visitors following repair, coupled with the extremely low embodied emissions of spare parts used (or not used in over 50% of repairs undertaken) re-enforces the value of Repair Cafés in reducing waste, minimizing consumption and helping communities attain a more circular economy.

It is hoped that the GHG emissions assessment methodology proposed and additional quantitative data presented, such as embodied category specific emissions and break-even periods, will help promote debate and advancement towards a more standardized approach to monitoring, reporting and further improving sustainability within the UK's repair community.

[60] This also assumes that a new product purchase continues to be deferred.

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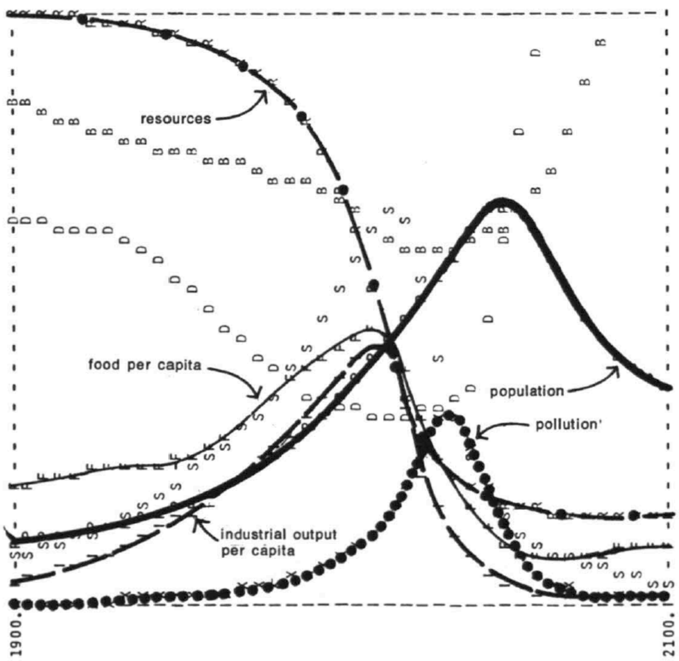
8 Appendices

Appendix A

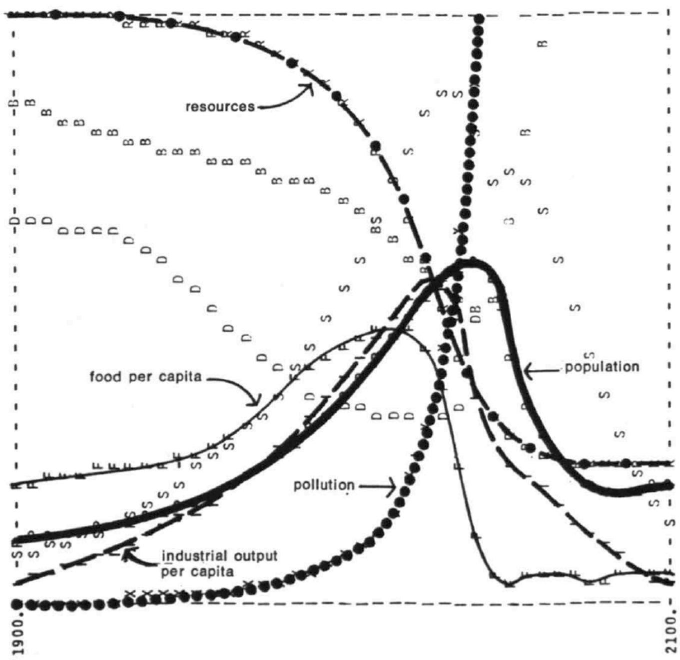
Club of Rome's forecast on world resource consumption (Meadows et al., 1972)

Figure 35 WORLD MODEL STANDARD RUN

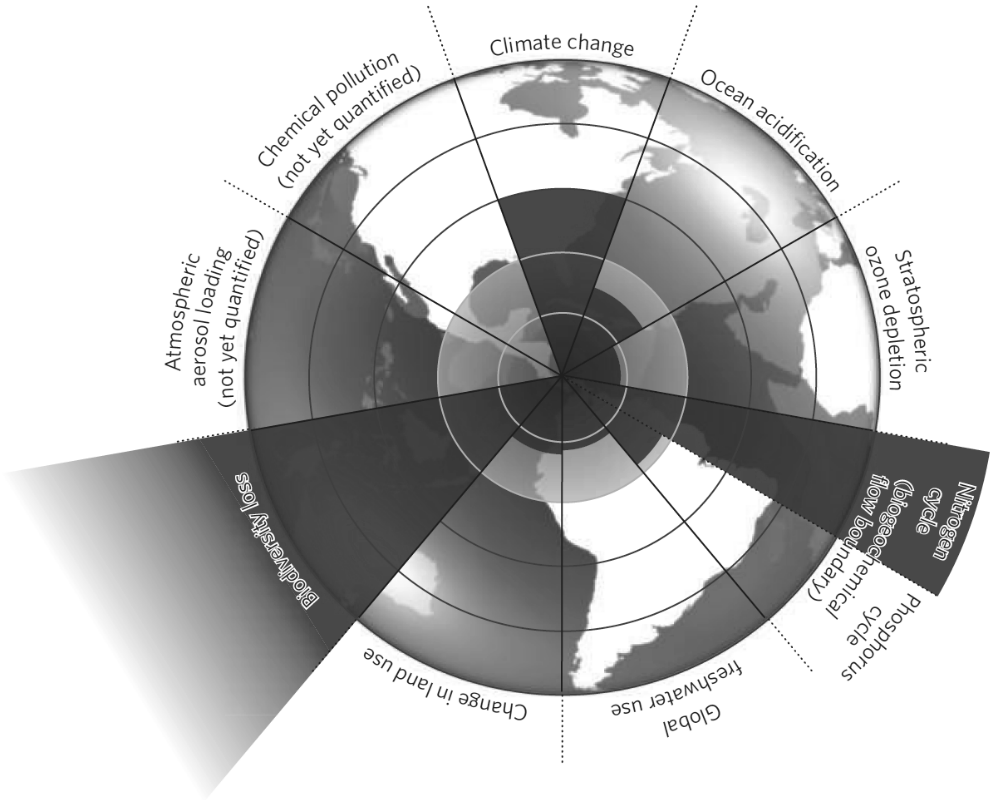


Revised model showing rise in pollution with increased resource availability.

Figure 36 WORLD MODEL WITH NATURAL RESOURCE RESERVES DOUBLED

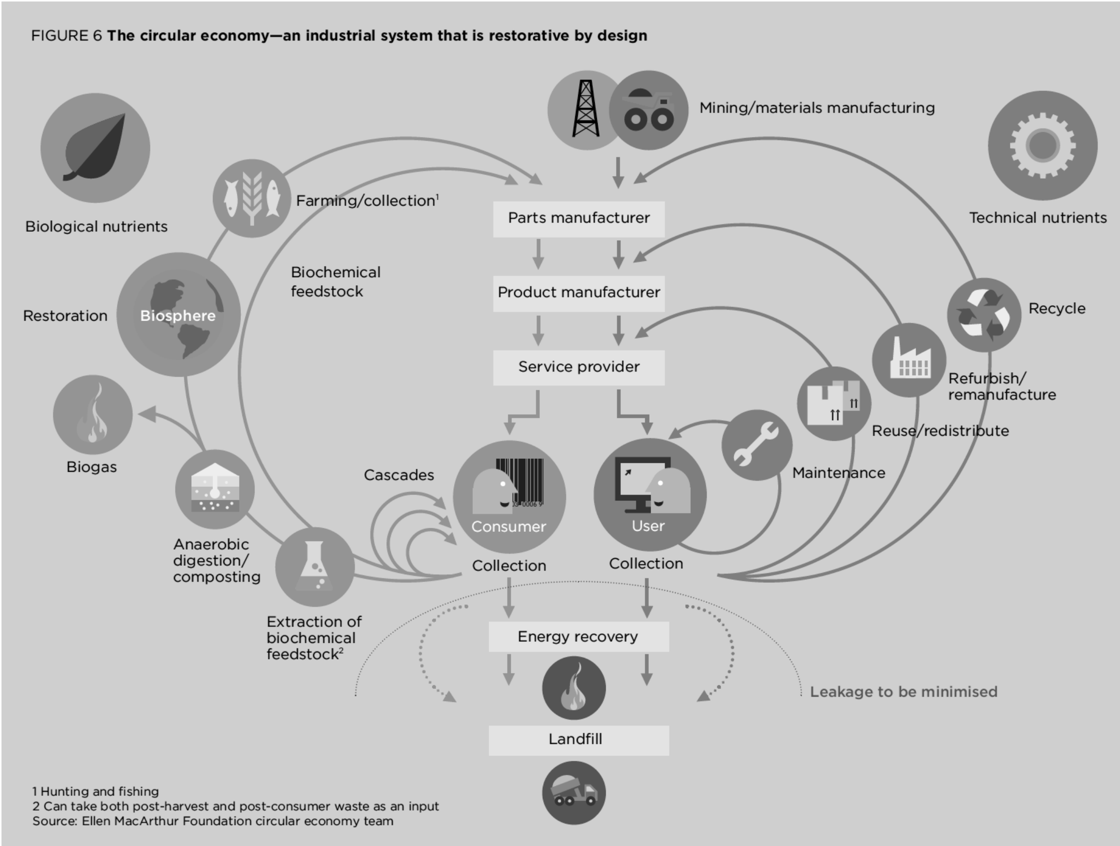


Appendix B   Concept of planetary boundaries



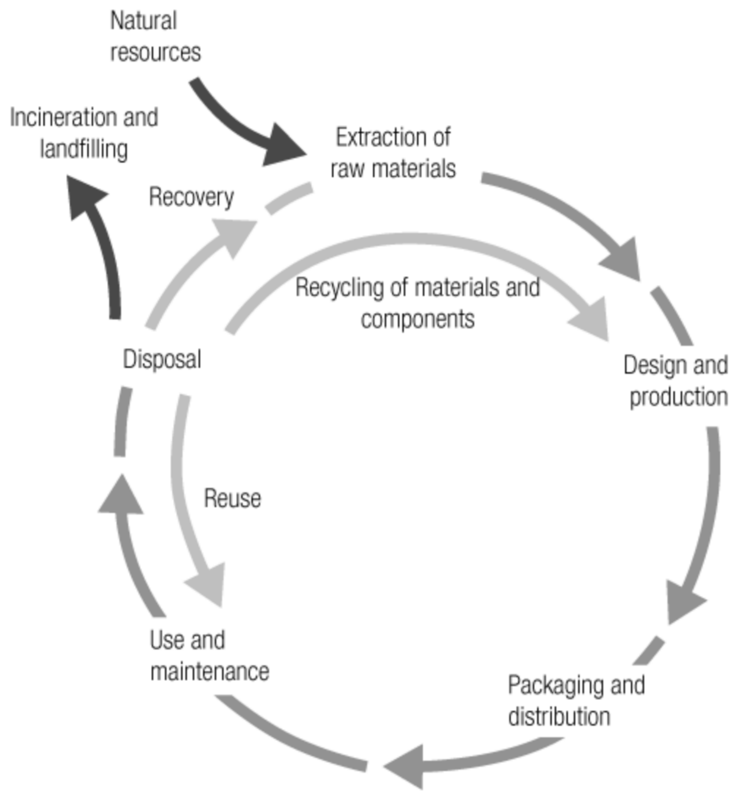
Source: NATURE|Vol 461|24 September 2009 proposed by Rockström et al., (2009)

Appendix C EMAF (2013) Model of Circular Economy



Source: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

Appendix D Lifecycle thinking stages during product lifecycle



Source: https://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/

Appendix E Online questionnaire developed for study

Community Repair Questionnaire

This questionnaire is part of a research project being undertaken at the University of Surrey, Centre for Environment and Sustainability. The questionnaire should take 10 - 12 minutes or less to complete.

If you have ever visited a community repair event and had an item repaired (or you work as a repair volunteer) your feedback will be extremely helpful in supporting ongoing research in this exciting area of sustainability. The data collected is being used to understand more about the prior history of products being taken for repair and what happens to these products afterwards. Data will also be used to more accurately consider the overall environmental benefits of community repair events.

Your responses are greatly appreciated and you will have the option to enter a prize draw for the chance to win a £50 Amazon or John Lewis (Waitrose) Voucher - once you have completed the questions AND clicked on SUBMIT.

*Note: Responses need to be received by 31st January 2018, and you may choose an alternative £50 voucher should you win.

Data protection and confidentiality: The information provided by you in the questionnaire will be used for research purposes and will not be used in a manner which would allow identification of your individual responses. Anonymised research data may be made available to other researchers/community repair event organisers. All contact e-mail address supplied for the purpose of notifying the prize winner will be destroyed once the prize winner is notified - Please note there is no obligation to enter the prize draw before submitting your responses. Should you have any questions please contact: Steve Privett (sp00497 at surrey dot ac dot uk)

* Required

Choice of Amazon or John Lewis Gift Voucher if you win*!

Or choose a voucher of your choice.

Community repair is where people bring along faulty household items such as clothing, electronics and bicycles for repair by expert volunteers.

1. **Q1 Have you ever taken a faulty item to a community repair event?**
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 32.*

About your item..

2. **Q2 What was the most recent faulty item you have taken to a repair event? For example, 'DAB Radio', 'Vacuum Cleaner', Trousers etc.** *

____

About your visit..

3. **Q2 (i) In which City, Town or Village was the community repair event held?** *

____

About your visit..

4. **Q2 (ii) How long ago did you take this item to the repair event?** *
Mark only one oval.

- ◯ Less than 1 month ago
- ◯ 1 month to 6 months ago
- ◯ 7 months to 11 months ago
- ◯ 1 - 2 years
- ◯ 2 - 3 years
- ◯ 3 - 4 years
- ◯ Don't know
- ◯ Other: ________________

About your item..

5.
Q3 Did you take more than one item for repair?
Mark only one oval.

- ◯ Yes *Skip to question 6.*
- ◯ No *Skip to question 7.*

6.
Q3 (i) How many items did you take? *

Mark only one oval.

- ◯ 2
- ◯ 3
- ◯ 4
- ◯ Other: ____________________

A few questions about your travel to the repair event..

7.
Q4 How far did you travel (approximately) from your home to the repair event (one way distance)? *

Mark only one oval.

- ◯ 1 mile or less
- ◯ 1 - 2 miles
- ◯ 2 - 3 miles
- ◯ 3 - 4 miles
- ◯ 4 - 5 miles
- ◯ 5 - 6 miles
- ◯ 6 - 7 miles
- ◯ 7 - 8 miles
- ◯ 8 - 9 miles
- ◯ 9 - 10 miles
- ◯ 10 - 12 miles
- ◯ 12 - 14 miles
- ◯ Don't know
- ◯ Other: ____________________

Cont.. A few questions about your travel to the repair event..

8.
Q5 What type of transport did you use for the majority of your journey? *

Mark only one oval.

- ◯ Car - (Van/4x4/SUV/EV/HEV)
- ◯ Motorcycle *Skip to question 12.*
- ◯ Bicycle *Skip to question 12.*
- ◯ Moped *Skip to question 12.*
- ◯ Bus *Skip to question 12.*
- ◯ Tram *Skip to question 12.*
- ◯ Train (overground) *Skip to question 12.*
- ◯ Train (underground) *Skip to question 12.*
- ◯ Mobility scooter (electric) *Skip to question 12.*
- ◯ Wheelchair *Skip to question 12.*
- ◯ Other: ____________________ *Skip to question 12.*

Cont.. A few questions about your travel to the repair event..

9.
Q5 (i) What size of car did you use? *

Mark only one oval.

- ◯ Small economy car - (such as Nissan Micra, Ford Ka, Citroen C1)
- ◯ Compact car - (such as Ford Fiesta, VW up!, Kia Picanto)
- ◯ Mid-size car - (such as Ford Focus, VW Golf)
- ◯ Full-size car - (such as Ford Mondeo, Vauxhall Insignia)
- ◯ Luxury car - (such as BMW 5 series, Audi A8, Jaguar XJ)
- ◯ Sports car - (such as Porsche Boxster, Audi TT, BMW Z4)
- ◯ SUV Sports Utility Vehicle (such as VW Tiguan, Ford Kuga, Toyota RAV4)
- ◯ 4x4 - (such as Range Rover, Land Rover, Volvo XC90)
- ◯ Van - (such as Ford Transit, Renault Trafic)
- ◯ Pick-up truck - (such as Mitsubishi L200, Nissan Navara)
- ◯ Don't know
- ◯ Other: ____________________

Cont.. A few questions about your travel to the repair event..

10. **Q5 (ii) What type of engine does this vehicle have?** *
Mark only one oval.

- ◯ Petrol
- ◯ Diesel
- ◯ Hybrid
- ◯ Electric *Skip to question 12.*
- ◯ Bi-fuel (LPG/Natural Gas)
- ◯ Don't know *Skip to question 12.*
- ◯ Other: ____________ *Skip to question 12.*

Skip to question 12.

Cont.. A few questions about your travel to the repair event..

11. **Q5 (iii) If you know the engine size (litres) please enter it below. For example 1.4 or 2.0. Please skip to the next question if you don't know.**

____

Cont.. A few questions about your travel to the repair event..

12. **Q6 What was the main purpose for your travel to the location (city/village/town) of the repair event?** *
Mark only one oval.

- ◯ To have the faulty item repaired
- ◯ The repair event was on route to somewhere I was travelling on the same day
- ◯ I was travelling to the area anyway to see friends or pursue a leisure activity
- ◯ I was travelling to the area anyway to shop
- ◯ I was working as a volunteer at the repair event
- ◯ Other: ____________

About the faulty item you took to the event...

If you took more than one item to the event please answer for the first item that was looked at by the repairer.

13. **Q7 How did you come to own the item?** *
Mark only one oval.

- ◯ It was a new purchase
- ◯ It was a gift (birthday, special occasion etc.)
- ◯ It was a used item someone didn't want/need and was given to me
- ◯ It was bought second hand (eBay, Gumtree, Jumble, Charity shop etc.)
- ◯ Other: ____________

About the faulty item you took to the event...

14. **Q8 Was the item working/functioning correctly when you first owned it?** *
Mark only one oval.

- ◯ Yes *Skip to question 17.*
- ◯ No

About the faulty item you took to the event...

15. **Q8 (i) Did you obtain the item knowing that it could possibly be repaired at a community repair event?** *
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 17.*

About the faulty item you took to the event...

16. **Q8 (ii) Would you have obtained the faulty item if you did not have access to community repair volunteers?** *
Mark only one oval.

- ◯ Yes
- ◯ No

About the faulty item you took to the event...

17. **Q9 Roughly how OLD was the item when you took it to the repair event (years since it was manufactured)?** *
Mark only one oval.

- Item had just been purchased (New)
- Less than 1 year
- 1 - 2 years
- 2 - 3 years
- 3 - 4 years
- 4 - 5 years
- 5 - 6 years
- 6 - 7 years
- 8 - 9 years
- 9 - 10 years
- 10 - 15 years
- 15 - 20 years
- Greater than 20 years
- Don't know

About the faulty item you took to the event...

18. **Q10 How LONG was the item FAULTY before you took it to the repair event?** *
Mark only one oval.

- Less than 1 month
- 1 month to 6 months
- 7 months to 11 months
- 1 - 2 years
- 2 - 3 years
- 3 - 4 years
- 4 - 5 years
- 5 - 6 years
- 6 - 7 years
- Don't know
- Other: ____________________

After the repair event what happened..

19. **Q11 Following your visit to the repair event was the item repaired?** *
Mark only one oval.

- Yes (it was completely successful and working again)
- Yes (it was not perfect but good enough to use again)
- No (the item could still not be used)
- Unknown at the moment (I left it for repair or I'm waiting for spare parts etc.) *Skip to question 31.*
- Other: ____________________

After the repair event what happened..

20. **Q12 What did you do with the item afterwards?** *
Mark only one oval.

- I am still using it successfully *Skip to question 23.*
- I used it for a time and then it became faulty again
- I sold it *Skip to question 23.*
- I kept it as a working spare *Skip to question 23.*
- I kept it for spares (as it was not possible to repair) *Skip to question 23.*
- I gave it away or donated it to a charity shop *Skip to question 23.*
- I took the item to a recycling point *Skip to question 23.*
- I disposed of the item (put it out for refuse collection) *Skip to question 23.*
- I kept the item for personal reasons although it was not working/usable *Skip to question 23.*
- Other: ____________________ *Skip to question 23.*

After the repair event what happened..

21. **Q12 (i) How long after being repaired did the item develop a fault again?**
Mark only one oval.

- Less than 1 month
- 1 month to 6 months
- 7 months to 11 months
- 1 - 2 years
- 2 - 3 years
- 3 - 4 years
- 4 - 5 years
- Don't know
- Other: ____________

After the repair event what happened..

22. **Q12 (ii) What did you do with the item once it became faulty?** *
Mark only one oval.

- I sold it
- I took it back to a community repair event to have it looked at again
- I kept it for spare parts
- I gave it away or donated it to a charity shop
- I took the item to a recycling point
- I disposed of the item (put it out for refuse collection)
- I kept the item for personal reasons although it was not working/usable
- I took/sent the item to a specialist or manufacturer repair service
- Other: ____________

After the repair event what happened..

23. **Q13 Did taking the faulty item to the repair event prevent you from purchasing a new or similar item?** *
Mark only one oval.

- Yes (it was repaired) *Skip to question 25.*
- No
- I decided not to replace the item with anything similar *Skip to question 25.*
- I am not sure at the moment *Skip to question 25.*
- Other: ____________ *Skip to question 25.*

After the repair event what happened..

24. **Q13 (i) How did you replace the faulty item?** *
Mark only one oval.

- I purchased a new product
- I bought a second hand item that worked
- Other: ____________

After the repair event what happened..

25. **Q14 Do you think you saved any money as a result of visiting the community repair event and having the product looked at by a repairer?** *
Mark only one oval.

- Yes
- No *Skip to question 27.*
- Maybe

After the repair event..

26. **Q14 (i) What did you do with the money saved?** *
Mark only one oval.

- I bought some additional household groceries, wine etc.
- Put the money towards a day out
- Put the money towards buying something else (new phone, vacuum cleaner, shirt, dress etc.)
- Donated the money to charity
- Treated myself or someone else to lunch or a meal out
- Put the money into a holiday fund
- Put the money into savings
- Don't know
- Other: ____________

In the future...

27. **Q15 Will you attend a community repair event again if you have a faulty product?** *
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe
- ( ) I'm a volunteer repairer

In the future...

28. **Q16 Did the experience of attending a community repair event motivate you to attempt the repair of anything yourself?** *
Mark only one oval.

- ( ) Yes
- ( ) No *Skip to question 31.*

About your own repair...

29. **Q16 (i) What item did you attempt to repair?** *

____

About your own repair...

30. **Q16 (ii) Was the repair successful?**
Mark only one oval.

- ( ) Yes (it was completely successful)
- ( ) Yes (it was not perfect but good enough to use again)
- ( ) No (the item could still not be used)
- ( ) Other: ________________________

Nearly finished...

31. **Q17 Any comments about your community repair experience you would like to add?**

____
____
____
____
____

Skip to question 34.

Nearly finished...

32. **Q18 Would you ever consider taking a faulty household item to a community repair event before disposing of or recycling it?** *
Mark only one oval.

- ( ) Yes *Skip to question 34.*
- ( ) No

Nearly finished...

33. **Q18 (i) Why would you not consider going to a community repair event?** *
Mark only one oval.

- ( ) Too far to travel
- ( ) Not aware of any community repair event in my area
- ( ) Don't have the time
- ( ) Not sure how much it might cost to repair
- ( ) Don't use the item enough to warrant the effort to fix it
- ( ) I'm unsure how good the repair might be
- ( ) I use maintenance/insurance cover when things become faulty
- ( ) Other: ________________________

Nearly Finished...

34. **Q18(ii) In which age group are you?**

Mark only one oval.

- ( ) 16 - 24
- ( ) 25 - 34
- ( ) 35 - 44
- ( ) 45 - 54
- ( ) 55 - 64
- ( ) 65 -74
- ( ) 75 - 84
- ( ) 85+
- ( ) Prefer not to say

35. **Q18(iii) What is your gender?**

Mark only one oval.

- ( ) Female
- ( ) Male
- ( ) Prefer not to say
- ( ) Other: ______________________

If you want to enter the prize draw please enter your e-mail below: If not, please click NEXT and Click SUBMIT - otherwise your data will not be received!!

Please enter your e-mail address if you want to be entered into the prize draw. You will be contacted via e-mail should you win to find out what type of voucher you would like.
Your e-mail address will ONLY be used to correspond with you should you win! It will NOT be supplied to any third-party.

OR

36. **Please enter your e-mail address below:**

____

Please click 'SUBMIT' to send your responses.

Appendix F Example of Newsletter promoting online questionnaire

Dear all

Happy new year!

Hope you have all had a good break and are ready to start the new year with good intentions. We can help with some of those - to grow more of your own food, waste less, do more to save the planet/help the community...

A few opportunities for volunteers in the preparation for Potato Day - packing seeds, making up pre-orders and helping on the day. Last year over 40 volunteers helped in various ways and it is always a lot of fun, so contact Steve, our Potato Day supremo, if you can help (details below). Our regular monthly meeting this Thursday will focus on pre-planning if you want to join us. We also have the first of our monthly Repair Cafes starting in February. If you have ever been along to one of our Repair Cafes, Steve, a Masters student from Farnham would appreciate it if you could answer a short survey about your experience.The questionnaire runs until the 15th January and there is a prize draw of £50, if you want to participate here.

Appendix G Example vehicle category CO_2 emitted per km calculation for compact cars.

Make	Model - Questionnaire catagopry Compact car - (such as Ford Fiesta, VW up!, Kia Picanto)	Model type. *See Note 1*	Engine size cubic cm	Fuel Type	Gov Pertol and Diesel (2009) average grams/km	Gov 2009 Test Data (Petrol) average grams/km	Gov 2009 Test Data (Diesel) average grams/km
Ford	Fiesta, Post 2008 Model Year	1.6 Duratorq TDCi (90PS)	1560	Diesel	116		116
Ford	Fiesta, Post 2008 Model Year	1.4 Duratorq TDCi (68PS)	1399	Diesel	119		119
Ford	Fiesta, Post 2008 Model Year	1.25 Duratec (75PS)	1242	Petrol	139	139	
Ford	Fiesta, Post 2008 Model Year	1.4 Duratec (80PS)	1388	Petrol	145	145	
Ford	Fiesta, Post 2008 Model Year	1.4 Duratec (80PS)	1388	Petrol	147	147	
Ford	Fiesta, Post 2008 Model Year	1.6 Duratec (100PS) - 4.25 FDR	1596	Petrol	153	153	
Ford	Fiesta, Post 2008 Model Year	1.6 Duratec (100PS) - 4.06 FDR	1596	Petrol	154	154	
Ford	Fiesta, Post 2008 Model Year	1.6 Duratec (100PS)	1596	Petrol	176	176	
Ford	Fiesta, Post 2008 Model Year	2.0 Duratec (150PS)	1999	Petrol	177	177	
VW	Polo	1.4 TDI (80 PS) BlueMotion with DPF	1422	Diesel	99		99
VW	Polo	1.4 TDI (70 PS)	1422	Diesel	119		119
VW	Polo	1.4 TDI (80 PS)	1422	Diesel	119		119
VW	Polo	1.9 TDI (100 PS)	1896	Diesel	127		127
VW	Polo	1.2 (60 PS)	1198	Petrol	138	138	
VW	Polo	1.2 (70 PS)	1198	Petrol	138	138	
VW	Polo	1.4 (80 PS)	1390	Petrol	150	150	
VW	Polo	1.6 (105 PS)	1598	Petrol	159	159	
VW	Polo	1.4 (80 PS) Tiptronic	1390	Petrol	165	165	
VW	Polo	1.8 T (150 PS) GTI	1781	Petrol	186	186	
Kia	Picanto	1.1 (14" wheels)	1086	Petrol	118	118	
Kia	Picanto	1.1 (15" wheels)	1086	Petrol	126	126	
Kia	Picanto	1.1 (14" wheels)	1086	Petrol	137	137	
				Average	**141.2**	**150.5**	**116.5**

Note 1: Download CO2 data for Euro 4 and Euro 5 engines
http://carfueldata.dft.gov.uk/downloads/download.aspx?rg=may2009

Appendix H Figures calculated for transportation (combustion) and embodied GHG emissions

Figures used for kg CO2e / km driven

Questionnaire transportation categories (for which there was a response)	Examples, notes:	Ave. Vehicle Weight 2009 Car-Com/Parkers Guide (Petrol) kgs	Ave. Vehicle Weight 2009 Car-Com/Parkers Guide (Diesel) kgs	Vehicle embodied Ave. grams CO2e / km (Petrol)*	Vehicle embodied Ave. grams CO2e / km (Diesel)*	Vehicle embodied Ave. grams CO2e / km (Electric)
Small economy car	Nissan Micra, Ford Ka, Citroen C1	892.4	963	26.9	29.0	70.0
Compact car	Ford Fiesta, VW up!, Kia Picanto	938.6	1042	28.3	31.4	N/A
Mid-size car	Ford Focus, VW Golf	1220.3	1307.8	36.7	39.4	N/A
Full-size car	Ford Mondeo, Vauxhall Insignia	1410.8	1475.6	42.5	44.4	N/A
Luxury car	BMW 5 series, Audi A8, Jaguar XJ	1532	1634.3	46.1	49.2	N/A
SUV Sports Utility Vehicle	VW Tiguan, Ford Kuga, Toyota RAV4	1465	1532	44.1	46.1	N/A
4x4	Range Rover, Land Rover, Volvo XC90	2227.7	2301.5	67.1	69.3	N/A
Van	Ford Transit, Renault Trafic	N/A	1720	N/A	51.8	N/A

Note: Embodied figures for public transport and non motorised transport are not considered.
* Assumes vehicle life of 150,000 km

Question transport response catagories	Examples, notes:	Gov 2009 Test Data (Petrol) average grams CO2e / km	Gov 2009 Test Data (Diesel) average grams CO2e / km	Electric car grams/km	Other transport modes grams CO2e / km	Notes:
Small economy car	Nissan Micra, Ford Ka, Citroen C1	150.6	118.0	59.0		
Compact car	Ford Fiesta, VW up!, Kia Picanto	150.5	116.5			
Mid-size car	Ford Focus, VW Golf	175.8	141.8			
Full-size car	Ford Mondeo, Vauxhall Insignia	201.4	153.4			
Luxury car	BMW 5 series, Audi A8, Jaguar XJ	213.4	176.2			
SUV	VW Tiguan, Ford Kuga, Toyota RAV4	190.4	171.4			
4x4	Range Rover, Land Rover, Volvo XC90	307.8	226.2			
Van	Ford Transit, Renault Trafic	N/A	220.6			
Bicycle					18.4	Average UK diet with imported food content
Bus					73.0	Regional 25% occupancy Euro IV compliant
Train (overground)					52.5	Regional Sprinter Diesel
Train (underground)					52.6	London Underground
Mobility scooter (electric)					31.0	Electric scooter using standard taffif electricity
Walked					24.2	Average UK diet with imported food content

Note: Transport catagories for which no resposes received have not been included.
Other transport modes figures sourced from: Camden council/Travelfootprint.org/ Clear Zone Partnership

Appendix I Embodied GHGs for different vehicle categories

Questionnaire transportation categories (as detailed in questionnaire)	Examples, notes:	Ave. Vehicle Weight 2009 Car-Com/Parkers Guide Petrol (kgs)	Ave. Vehicle Weight 2009 Car-Com/Parkers Guide Diesel (kgs)	Vehicle embodied Ave. (grams CO2e/km) Petrol*	Vehicle embodied Ave. (grams CO2e/km) Diesel*	Vehicle embodied Ave. (grams CO2e/km) Electric	Vehicle embodied Ave. (grams CO2e/km) Hybrid
Small economy car	Nissan Micra, Ford Ka, Citroen C1	892.4	963	26.9	29.0	73.0	N/A
Compact car	Ford Fiesta, VW up!, Kia Picanto	938.6	1042	28.3	31.4	N/A	N/A
Mid-size car	Ford Focus, VW Golf	1220.3	1307.8	36.7	39.4	N/A	N/A
Full-size car	Ford Mondeo, Vauxhall Insignia	1410.8	1475.6	42.5	44.4	N/A	N/A
Luxury car	BMW 5 series, Audi A8, Jaguar XJ	1532	1634.3	46.1	49.2	N/A	N/A
SUV Sports Utility Vehicle	VW Tiguan, Ford Kuga, Toyota RAV4	1465	1532	44.1	46.1	N/A	50.1
4x4	Range Rover, Land Rover, Volvo XC90	2227.7	2301.5	67.1	69.3	N/A	N/A
Van	Ford Transit, Renault Trafic	N/A	1720	N/A	51.8	N/A	N/A

Note: Embodied figures for public transport and non motorised transport are not considered.
* Assumes vehicle life of 150,000 km

Appendix J Defra landfill and recycling GHG emission figures 2017

Waste type	Unit	Landfill kg CO_2e	Open-loop kg CO_2e	Closed-loop kg CO_2e
Aggregates	tonnes	1.4	1.1	1.1
Average construction	tonnes		1.4	1.1
Asbestos	tonnes	1.4		
Asphalt	tonnes	1.4	1.4	1.1
Bricks	tonnes	1.4	1.1	
Concrete	tonnes	1.4	1.1	1.1
Insulation	tonnes	1.4		1.1
Metals	tonnes	1.4		1.1
Soils	tonnes	16.3		1.1
Mineral oil	tonnes			21.8
Plasterboard	tonnes	72.0		21.8
Tyres	tonnes		21.8	21.8
Wood	tonnes	819.1	21.8	21.8

Waste type	Unit	Landfill kg CO_2e	Open-loop kg CO_2e	Closed-loop kg CO_2e
Books	tonnes	1,042.2		21.8
Glass	tonnes	26.0	21.8	21.8
Clothing	tonnes	445.3		21.8

Waste type	Unit	Landfill kg CO2e	Open-loop kg CO2e
WEEE - fridges and freezers	tonnes	16.6	21.8
WEEE - large	tonnes	16.6	21.8
WEEE - mixed	tonnes	16.6	21.8
WEEE - small	tonnes	16.6	21.8
Batteries	tonnes	75.5	64.6

Waste type	Unit	Landfill kg CO2e	Closed-loop kg CO2e
Metal: aluminium cans and foil (excl. forming)	tonnes	9.3	21.8
Metal: mixed cans	tonnes	9.3	21.8
Metal: scrap metal	tonnes	9.3	21.8
Metal: steel cans	tonnes	9.3	21.8

Waste type	Unit	Landfill kg CO2e	Open-loop kg CO2e	Closed-loop kg CO2e
Plastics: average plastics	tonnes	9.3	21.8	21.8
Plastics: average plastic film	tonnes	9.3	21.8	21.8
Plastics: average plastic rigid	tonnes	9.3	21.8	21.8
Plastics: HDPE (incl. forming)	tonnes	9.3	21.8	21.8
Plastics: LDPE and LLDPE (incl. forming)	tonnes	9.3	21.8	21.8
Plastics: PET (incl. forming)	tonnes	9.3	21.8	21.8
Plastics: PP (incl. forming)	tonnes	9.3	21.8	21.8
Plastics: PS (incl. forming)	tonnes	9.3	21.8	21.8
Plastics: PVC (incl. forming)	tonnes	9.3	21.8	21.8

Waste type	Unit	Landfill kg CO2e	Closed-loop kg CO2e
Paper and board: board	tonnes	1,042.2	21.8
Paper and board: mixed	tonnes	1,042.2	21.8
Paper and board: paper	tonnes	1,042.2	21.8

Data Source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017

Appendix K Table of embodied GHGs calculated for each product type and references used

Item	Item ID	Study 1 LCA weight (kg)	Total GWP kg CO2e	GWP kg CO2e /kg	Study 1 reference	Study 2 LCA weight (kg)	Total GWP kg CO2	GWP kg CO2e /kg3	Study 2 reference	Study 3 LCA weight (kg)	Total GWP kg CO2	GWP kg CO2e / kg	Study 3 reference	Average GWP kg CO2e / kg
Anglepoise Lamp	220	4.6	34.8	7.57	Eco Audit									7.6
Bag (cloth)	48	0.22	7.37	33.50	**7 (cotton)**	1000	12261	12.26	**11 (linen)**	1.72	73	42.44	**12 (leather)**	29.4
Bicycle pedal (non elec)	391	19.9	96	4.82	**1**	18	314.8	17.49	**2**	15	111.4	7.43	**3**	9.9
Blanket (quilt/duvet)	20	1	46.3	46.30	**9 (wool)**	1	21.3	21.30	**9 (polyester)**	1	15	15.00	**9 (linen)**	27.5
Bracelet	260	0.021	0.38	18.10	Eco Audit									18.1
Brooch	261	0.021	0.38	18.10	Eco Audit									18.1
Camera (digital)	1	0.3	8.1	27.00	**38**	0.47	99.8	212.34	Eco Audit					119.7
Camera (modern 35mm)	2	1	63.4	63.40	See notes									63.4
Cardigan	43	1	46.3	46.30	**9 (wool)**	0.446	13.4	30.04	**7**	1	38.4	38.40	**9 (acrylic)**	38.2
CD/DVD player	180	2.5	67.5	27.00	38									27.0
Chair (mixed materials)	221	1	1.49	1.49	**27 (min 2)**	1	4.03	4.03	**27 (max 2)**	1	0.867	0.87	**28**	2.1
Clock (electronic)	225	0.27	2.75	10.19	Eco Audit									10.2
Clock (mechanical)	226	3.1	12.3	3.97	Eco Audit									4.0
Clothes steamer	375	3.09	28.1	9.09	See notes									9.1
Coat	21	1	30.1	30.10	**9 (viscouse)**	1	14.9	14.90	**9 (mix min)**	1	35.7	35.70	**9 (mix max)**	26.9
Coffee machine (elec.)	281	2.5	25	10.00	**30**	1.84	18	9.78	**30**	4.87	36	7.39	**30**	9.1
Curtains	227	1000	23637	23.64	**11 (silk)**	1000	26096	26.10	**11 (cotton)**	1000	12261	12.26	**11 (linen)**	20.7
DAB/FM portable radio	181	2	54	27.00	**38**									27.0
Dehumidifier	114	7.6	79.05	10.40	**29**									10.4
Dress	22	1	14.3	14.30	**11**	1000	26096	26.10	**11 (cotton)**	1000	12261	12.26	**11 (linen)**	17.6
Drill (elec.)	144	1.69	26.6	15.74	**20**									15.7
Earrings (metal)	265	0.011	1.07	97.27	Eco Audit									97.3
Electric heater/radiator	115	3.7	10.8	2.92	Eco Audit									2.9
Extension cable	145	0.63	3.73	5.92	Eco Audit									5.9
Fan (elec.)	116	1.5	17	11.33	Eco Audit									11.3
Food mixer/blender (elec.)	283	1.69	26.6	15.74	**20**									15.7
Glasses (specticals)	23	0.11	0.579	5.26	Eco Audit (nylon)	0.095	0.849	8.94	Eco Audit (titanium)					7.1
Hair straightener/tongs	372	0.41	4	9.76	See notes	0.365	3	8.22	See notes					9.0
Hairdryer	117	0.41	4	9.76	**31**	0.365	3	8.22	**31**					9.0
Handbag	25	1	29.4	29.40	See notes									29.4
Headphones (over-ear)	182	0.088	0.623	7.08	Eco Audit									7.1
Hedge trimmer (elec.)	147	4.7	19.1	4.06	Eco Audit	1.69	26.6	15.74	20	2.8	23.1	8.25	Eco Audit	9.4
Hi-Fi amplifier	183	7.5	202.5	27.00	**38**									27.0
Hi-Fi music system	184	15	405	27.00	**38**									27.0
Iron (steam)	118	3.09	28.1	9.09	See notes									9.1
Jacket (cloth)	27	0.22	7.37	33.50	**7 (cotton)**	1	21.3	21.30	**9 (polyester)**	0.446	13.4	30.04	**7**	28.3
Jumper	47	1	46.3	46.30	**9 (wool)**	1000	26096	26.10	**11 (cotton)**	1000	19055	19.06	**11 (Polyester)**	30.5
Kettle (elec.)	285	0.7	21.74	31.06	**25**									31.1
Laptop	65	2.06	458	222.33	**4**	3.8	249	65.53	**5**	2.54	200	78.74	**6**	122.2
Lighting (decorative)	231	0.69	12.3	17.83	Eco Audit									17.8

Note: Where a study reference number is given it should be cross referenced to the List of LCA references used.

Continued on next page

..continued

Item	Item ID	Study 1 LCA weight (kg)	Total GWP kg CO2e	GWP kg CO2e /kg	Study 1 reference	Study 2 LCA weight (kg)	Total GWP kg CO2e2	GWP kg CO2e /kg3	Study 2 reference	Study LCA weight (kg)	Total GWP kg CO2e4	GWP kg CO2e /kg5	Study 3 reference	Average kg CO2e /kg
Loppers	164	2	13.7	6.85	Eco Audit									6.9
Microwave oven	287	11.5	150	13.04	**19**									13.0
Mower (electrical)	149	37.8	152.5	4.03	**36**									4.0
Musical instrument (wood)	187	3.9	15.3	3.92	Eco Audit									3.9
Necklace	262	0.03	2.1	70.00	Eco Audit									70.0
Ornament (china/glass)	232	1.5	4.5	3.00	Eco Audit									3.0
Phone (DEC)	373	0.26	20	76.92	See notes									76.9
Pressure washer (elec.)	153	5.5	32.45	5.90	See notes									5.9
Printer	69	22.3	205.2	9.20	**32**	26	234.9	9.03	**40**	2.8	41	14.64	Eco Audit	11.0
Razor (elec.)	364	0.61	23.2	38.03	Eco Audit									38.0
Rucksack	31	1	19.8	19.80	**9 (polypropylene)**	1000	17378	17.38	**11 (poly mix)**	1000	26096	26.10	**11 (cotton)**	21.1
Secateurs	155	0.29	0.926	3.19	Eco Audit									3.2
Sewing machine	119	8.62	35	4.06	**35**									4.1
Shears	156	1.6	7.99	4.99	Eco Audit									5.0
Shirt	35	0.22	7.37	33.50	**7 (cotton)**	0.25	5.5	22.00	**11 (top)**	1	21.3	21.30	**9 (polyester)**	25.6
Shoes	36	0.66	3.386	5.13	**14**	0.66	25.264	38.28	**14**	0.66	13.61	20.62	**15**	21.3
Shredder (paper)	120	1.69	26.6	15.74	See notes									15.7
Skirt	37	1	38.4	38.40	**9 (acrylic)**	1	21.3	21.30	**9 (polyester)**	1	15	15.00	**9 (linen)**	24.9
Smart phone	366	0.152	48.1	316.45	**15**	0.143	34.74	242.94	**17**	0.138	45.36	328.70	**18**	296.0
Spade/fork (non powered)	157	1.8	6.41	3.56	Eco Audit (wood)	1.6	8.57	5.36	Eco Audit (plastic)					4.5
Speakers	73	2.3	62.1	27.00	**38**									27.0
Standard lamp	237	4.6	17.7	3.85	Eco Audit									3.8
Staple gun	169	0.76	3.04	4.00	Eco Audit	0.185	1.265	6.84	39					5.4
Suitcase	311	5.1	24.7	4.84	Eco Audit									4.8
Table (wood/metal)	238	36.66	47.7	1.30	**26**	1	0.43	0.43	**27 (min)**	1	4.84	4.84	**27 (max)**	2.2
Table lamp (metal)	242	2.6	18.1	6.96	Eco Audit									7.0
Table lamp (wood)	239	3.7	14.4	3.89	Eco Audit									3.9
Tablet (iPad)	71	0.299	105.6	353.18	**33**	0.692	240.3	347.25	**34**	0.395	188.34	476.81	**10**	392.4
Tape/cassette recorder	190	1	27	27.00	**38**									27.0
Toaster (elec.)	288	1.3	6.29	4.84	Eco Audit	3.4	15	4.41	Eco Audit					4.6
Torch (battery)	159	0.56	2.96	5.29	Eco Audit									5.3
Toy (electronic/plastic)	191	1.05	7.41	7.06	**37**									7.1
Toy (soft)	41	1	21.3	21.30	**9 (polyester)**	1	46.3	46.30	**9 (wool)**	1	25.3	25.30	**9 (fabric mix)**	31.0
Trousers	40	0.22	7.37	33.50	**7**	0.4	20.04	50.10	**8 (denim)**	1	15	15.00	**9 (linen)**	32.9
TV (LCD)	194	11.81	288	24.39	**21**	52.5	572	10.90	**21**	12.47	210	16.84	**22**	17.4
Vacuum cleaner	121	8.62	45	5.22	**23 (cannister)**	3.5	25	7.14	**24**	7.91	42	5.31	**23 (upright domest**	5.9
Vacuum cleaner (battery)	124	6.83	36	5.27	**23 (cordless)**									5.3
VCR cassette recorder	196	1	27	27.00	**38**									27.0
Watch (battery)	263	0.029	0.677	23.34	Eco Audit									23.3

Notes: Eco Audit BOMs, weight and material assumptions can be seen in Appendix section
For details on Eco Audit software http://coral.ufsm.br/righi/Materiais/FIGS/ch7bnotes.pdf

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Appendix L Letter requesting repair data from Repair Cafés

Dear Repair Café Organiser,

RE: UK Study of Community Repair and its potential impact on Carbon Emissions

Could you please help if possible with my student research study being carried out at the University of Surrey (Centre for Environment and Sustainability), to estimate the potential carbon savings from the increase in community repair activities across the UK.

To undertake this research, I am asking Repair Cafés across the UK if they would kindly supply any **existing data** they may have collected about the products brought for repair **since their events started**.

How will this data be used? Any data you provide will be used to build a profile of the products being repaired and enable estimates of the overall amount of carbon being saved by displacing new product purchases.

When the study is completed the results should help community repairers more accurately report CO_2 savings from their repair sessions and give a bigger picture of community repair impact across the UK. It is hoped that more research in this area will help support the need to maintain and extend consumer access to spare parts and the rights to repair the products they own.

What type of data is helpful? All data is potentially helpful, some examples of the data that may have been collected in a spreadsheet for event sessions is:

- Number of visitors
- Details of individual products or categories of products seen
- Product faults, diagnosis and repair outcomes
- Possibly the weight of individual products

Whatever data you have will help make the study more reliable and robust. Please note that data will be aggregated and it will not be possibly to identify individual data sources in any published material.

You can e-mail any data you can share directly to mailto:sp00497@surrey.ac.uk Should you have any questions please e-mail or call me on: 01234 567890.

I very much appreciate your help - should you kindly supply your data for this study you will automatically be entered into a prize draw to win a £50 Amazon or John Lewis Voucher!

With thanks,

Steve Privett

e-mail: sp00497@surrey.ac.uk
mobile: 01234 567890

To find out more about sustainability research at the University of Surrey please follow this link to CES

Appendix M 79 most commonly seen products and general product category assignment

Product type	General product category
Bag (cloth)	Clothing & textiles
Blanket (quilt/duvet)	Clothing & textiles
Cardigan	Clothing & textiles
Coat	Clothing & textiles
Curtains	Clothing & textiles
Dress	Clothing & textiles
Handbag	Clothing & textiles
Jacket (cloth)	Clothing & textiles
Jumper	Clothing & textiles
Rucksack	Clothing & textiles
Shirt	Clothing & textiles
Shoes	Clothing & textiles
Skirt	Clothing & textiles
Toy (soft)	Clothing & textiles
Trousers	Clothing & textiles
Laptop	Computing, IT and mobile
Phone (DEC)	Computing, IT and mobile
Printer	Computing, IT and mobile
Smart phone	Computing, IT and mobile
Tablet (iPad)	Computing, IT and mobile
Anglepoise Lamp	Household appliances
Clock (electronic)	Household appliances
Clothes steamer	Household appliances
Coffee machine (elec.)	Household appliances
Dehumidifier	Household appliances
Electric heater/radiator	Household appliances
Fan (elec.)	Household appliances
Food mixer/blender (elec.)	Household appliances
Hair straightener/tongs	Household appliances
Hairdryer	Household appliances
Iron (steam)	Household appliances
Kettle (elec.)	Household appliances
Lighting (decorative)	Household appliances
Microwave oven	Household appliances
Razor (elec.)	Household appliances
Sewing machine	Household appliances
Shredder (paper)	Household appliances
Standard lamp	Household appliances
Table lamp (metal)	Household appliances
Table lamp (wood)	Household appliances
Toaster (elec.)	Household appliances
Toy (electronic/plastic)	Household appliances
Vacuum cleaner	Household appliances
Vacuum cleaner (battery)	Household appliances
Drill (elec.)	Garden & DIY power tools
Hedge trimmer (elec.)	Garden & DIY power tools
Mower (electrical)	Garden & DIY power tools
Pressure washer (elec.)	Garden & DIY power tools
Camera (digital)	Audio and AV/Photo
Camera (modern 35mm)	Audio and AV/Photo
CD/DVD player	Audio and AV/Photo
DAB/FM portable radio	Audio and AV/Photo
Headphones (over-ear)	Audio and AV/Photo
Hi-Fi amplifier	Audio and AV/Photo
Hi-Fi music system	Audio and AV/Photo
Speakers	Audio and AV/Photo
Tape/cassette recorder	Audio and AV/Photo
TV (LCD)	Audio and AV/Photo
VCR cassette recorder	Audio and AV/Photo
Chair (mixed materials)	Furniture
Table (wood/metal)	Furniture
Loppers	Tools (non elec.)
Secateurs	Tools (non elec.)
Shears	Tools (non elec.)
Spade/fork (non powered)	Tools (non elec.)
Staple gun	Tools (non elec.)
Clock (mechanical)	Other household
Extension cable	Other household
Musical instrument (wood)	Other household
Ornament (china/glass)	Other household
Suitcase	Other household
Torch (battery)	Other household
Bracelet	Jewellery
Brooch	Jewellery
Earrings (metal)	Jewellery
Glasses (specticals)	Jewellery
Necklace	Jewellery
Watch (battery)	Jewellery
Bicycle pedal (non elec)	Bicycles

Appendix N Breakdown by Repair Café of completed repair outcomes

Data source	Items within top 79 products	Repair % covered by top 79 products	% Outcome recorded as Completed in top 79 products
Repair Café 1	167	84.3	**75.4**
Repair Café 2	16	84.2	62.5
Repair Café 3	145	87.9	51.7
Repair Café 4	93	85.3	53.8
Repair Café 5	108	85.7	**52.8**
Repair Café 6	184	78.0	63.6
Repair Café 7	155	81.2	66.5
Repair Café 8	509	79.8	65.8
Repair Café 9	172	82.3	65.7
Repair Café 10	27	90.0	48.1
Repair Café 11	603	84.1	53.7
Repair Café 12	41	80.4	100.0
Repair Café 13	136	83.4	59.6
Totals	2356	83.6	63.0
		Unweighted Ave	Unweighted Ave

Repair Café 12 reported 100% success: this was queried with the organizers (see Appendix O) who confirmed this figure as being correct for the 51 repairs that had been undertaken.

Appendix O E-mail correspondence checking about completed repair success rate.

Inquiry:

Hi [redacted],

Sorry to trouble you.. please could you answer a couple of questions about the data you sent me..

1) Could you let me know what date the data you sent relates to… is it from two events in 2017?
2) The data appears to be for successfully repaired items only.. is there a list that shows both the repaired and non repaired items for these events?

Part of the analysis is looking at which items can and cannot be repaired easily, so it is helpful to know what the non repaired items are. :)

Many thanks,
Steve

Response:

Hi Steve,

I don't think our repair cafe stats have any dates on them (we don't need that info) - We've had two repair cafe's in 2017 - one in August and the other in October. I think we repaired more at our first than second - the later ones in the sheet will be the newer ones. Our next one is scheduled for the 10th Feb (https://www.facebook.com/[redacted]) We don't collate info on what was repaired/not at the cafe - if we can't fix something it is usually followed up on by our team if not able to fix at the time but it's all recorded as under that event. I'm not sure if there's anything we can't fix at all. Sorry, that's perhaps not the most helpful for you.

Appendix P Repair Café repair success rates by product type in descending order

Product type	Number of items presented (n)	Completed %	Partial %	Not completed %	Advice given %
Trousers	118	96.5	1.8	1.8	0.0
Coat	24	95.8	4.2	0.0	0.0
Dress	22	95.2	4.8	0.0	0.0
Jumper	27	91.7	4.2	4.2	0.0
Bag (cloth)	25	87.0	13.0	0.0	0.0
Skirt	21	85.7	4.8	4.8	4.8
Handbag	26	84.6	0.0	15.4	0.0
Necklace	87	84.0	8.6	4.9	2.5
Shirt	32	83.3	6.7	10.0	0.0
Bicycle pedal (non elec)	206	83.2	7.1	8.4	1.3
Hedge trimmer (elec.)	39	78.9	2.6	18.4	0.0
Brooch	22	78.9	10.5	10.5	0.0
Jacket (cloth)	28	78.6	7.1	14.3	0.0
Rucksack	18	77.8	11.1	11.1	0.0
Bracelet	20	77.8	11.1	11.1	0.0
Table lamp (metal)	114	77.1	9.2	11.9	1.8
Sewing machine	70	73.1	9.0	14.9	3.0
Toy (electronic/plastic)	47	72.1	4.7	23.3	0.0
Vacuum cleaner	87	70.6	8.2	20.0	1.2
Table (wood/metal)	18	70.6	17.6	11.8	0.0
Lighting (decorative)	22	68.4	5.3	21.1	5.3
Drill (elec.)	24	68.2	4.5	27.3	0.0
Chair (mixed materials)	50	68.0	8.0	20.0	4.0
Mower (electrical)	31	64.5	16.1	19.4	0.0
Clock (electronic)	37	62.2	5.4	27.0	5.4
Electric heater/radiator	21	61.9	0.0	38.1	0.0
DAB/FM portable radio	148	61.2	9.7	23.9	5.2
Hi-Fi amplifier	19	58.8	0.0	35.3	5.9
Hairdryer	25	54.2	8.3	37.5	0.0
Torch (battery)	35	52.9	2.9	32.4	11.8
Hi-Fi music system	24	52.2	13.0	30.4	4.3
Tape/cassette recorder	21	50.0	15.0	20.0	15.0
Hair straightener/tongs	19	50.0	12.5	31.3	6.3
Toaster (elec.)	61	49.1	9.4	41.5	0.0
Watch (battery)	29	48.0	20.0	24.0	8.0
Headphones (over-ear)	19	47.1	5.9	47.1	0.0
Food mixer/blender (elec.)	55	46.2	7.7	36.5	9.6
Iron (steam)	37	44.1	14.7	38.2	2.9
CD/DVD player	61	43.6	9.1	43.6	3.6
Printer	24	39.1	8.7	39.1	13.0
Tablet (iPad)	21	38.9	22.2	38.9	0.0
Smart phone	22	35.0	0.0	50.0	15.0
Laptop	98	32.9	16.5	32.9	17.6
Kettle (elec.)	42	29.3	4.9	65.9	0.0
Total items	1996				

For product where number of recorded repairs for product type > 15

Appendix Q Average product weights for 79 most commonly repaired products

Item	Weight Min (kg)	Weight Max (kg)	Weight Ave. (kg) all rec. values	Weight sample (n)	Notes
Anglepoise Lamp	2.62	4.00	3.44	3	See Note 1
Bag (cloth)	0.10	1.30	0.58	9	
Bicycle pedal (non elec)	6.00	20.00	15.09	27	
Blanket (quilt/duvet)	0.15	2.80	1.48	3	
Bracelet	0.04	0.14	0.08	3	See Note 2
Brooch	0.04	0.20	0.10	3	See Note 2
Camera (digital)	0.30	0.60	0.47	3	
Camera (modern 35mm)	0.25	0.99	0.56	3	
Cardigan	0.18	0.60	0.41	3	See Note 2
CD/DVD player	1.20	6.00	2.77	14	
Chair (mixed materials)	2.00	18.00	7.62	19	
Clock (electronic)	0.10	3.90	1.26	7	
Clock (mechanical)	0.24	4.20	2.00	3	See Note 3
Clothes steamer	0.91	9.98	6.08	3	See Note 3
Coat	0.12	1.50	0.78	10	
Coffee machine (elec.)	1.00	2.80	1.93	3	
Curtains	1.00	6.70	2.92	6	
DAB/FM portable radio	0.25	4.50	1.61	44	
Dehumidifier	5.30	11.10	7.60	3	See Note 2
Dress	0.15	2.22	0.79	5	
Drill (elec.)	1.00	2.00	1.69	5	
Earrings (metal)	0.01	0.02	0.01	3	See Note 3
Electric heater/radiator	1.00	8.00	3.28	5	
Extension cable	0.15	1.00	0.63	3	
Fan (elec.)	0.15	2.60	1.38	4	
Food mixer/blender (elec.)	0.85	9.50	4.04	8	
Glasses (specticals)	0.10	0.50	0.27	3	
Hair straightener/tongs	0.24	2.00	1.08	3	See Note 1
Hairdryer	0.25	1.00	0.64	8	
Handbag	0.37	1.00	0.65	6	
Headphones (over-ear)	0.20	1.00	0.43	6	
Hedge trimmer (elec.)	2.00	10.50	4.08	16	
Hi-Fi amplifier	1.10	8.40	4.50	4	
Hi-Fi music system	2.00	18.50	6.91	8	
Iron (steam)	0.80	1.60	1.20	9	
Jacket (cloth)	0.20	1.90	0.81	8	
Jumper	0.10	0.80	0.37	13	
Kettle (elec.)	0.80	1.60	1.04	7	
Laptop	1.00	3.50	2.49	10	
Lighting (decorative)	0.10	2.97	0.90	6	
loppers	1.10	1.24	1.18	3	See Note 1
Microwave oven	5.00	13.30	9.77	3	
Mower (electrical)	6.50	18.00	10.17	11	
Musical instrument (wood)	0.45	2.90	1.78	3	See Note 2
Necklace	0.01	0.12	0.05	3	
Ornament (china/glass)	0.54	1.70	1.09	3	See Note 3
Phone (DEC)	0.50	2.00	1.33	3	
Pressure washer (elec.)	4.34	6.50	5.55	3	See Note 4
Printer	0.50	6.20	2.81	5	
Razor (elec.)	0.40	1.00	0.63	3	See Note 1
Rucksack	0.50	1.20	0.79	7	
Secateurs	0.15	1.51	0.60	6	
Sewing machine	4.00	15.00	8.62	35	
Shears	0.87	1.27	1.08	3	See Note 1
Shirt	0.06	0.50	0.25	5	
Shoes	0.30	1.18	0.66	3	See Note 1
Shredder (paper)	2.90	5.40	3.78	3	See Note 3
Skirt	0.14	1.00	0.48	5	
Smart phone	0.10	0.15	0.13	3	See Note 1
Spade/fork (non powered)	0.50	2.00	1.32	3	
Speakers	4.00	9.20	6.27	3	See Note 2
Standard lamp	0.60	7.00	4.44	7	
Staple gun	0.25	1.03	0.76	3	See Note 1
Suitcase	3.70	4.68	4.13	3	See Note 1
Table (wood/metal)	1.00	15.00	6.30	8	
Table lamp (metal)	0.35	10.00	2.52	36	
Table lamp (wood)	0.50	6.50	2.38	4	
Tablet (iPad)	0.30	1.00	0.73	3	
Tape/cassette recorder	0.20	4.00	1.40	4	
Toaster (elec.)	1.60	3.90	2.29	13	
Torch (battery)	0.35	0.50	0.46	4	
Toy (electronic/plastic)	0.10	4.60	0.81	16	
Toy (soft)	0.10	1.25	0.54	3	See Note 1
Trousers	0.10	1.80	0.53	28	
TV (LCD)	2.00	4.80	3.27	6	See Note 1
Vacuum cleaner	1.60	10.70	6.28	32	
Vacuum cleaner (battery)	1.29	2.58	1.92	3	See Note 3
VCR cassette recorder	3.30	6.00	4.73	3	See Note 2
Watch (battery)	0.05	0.50	0.17	5	
Totals	1.35	4.79	2.75	606	

Weight data used is from 3 primary data sets that measured item weights.
Note 1: Weight data uses supplementary data for 1 sample.
Note 2: Weight data uses supplementary data for 2 samples.
Note 3: Weight data uses supplementary data for 3 samples.

Appendix R Example bills of materials for calculating embodied GHGs using EcoAudit 2017

Please note that all product bills of materials used for this study are available upon request.

	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 1 year product life):	34.766

Anglepoise Lamp - Detailed breakdown of individual life

Material:

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	CO2 footprint (kg)	%
Aluminium shade	Non age-hardening wrought Al-alloys	Virgin (0%)	0.12	1	0.12	1.58	5.2
Brass shade cap	Brass	Virgin (0%)	0.05	1	0.05	0.18	0.6
Aluminium supports	Non age-hardening wrought Al-alloys	Virgin (0%)	0.20	4	0.80	10.51	34.9
Cast iron base	Cast iron, gray	Virgin (0%)	2.00	1	2.00	3.40	11.3
Base cover	Medium carbon steel	Virgin (0%)	0.30	1	0.30	0.54	1.8
U-backet upright	Cast Al-alloys	Virgin (0%)	0.30	1	0.30	3.63	12.0
Pins	Stainless steel	Virgin (0%)	0.01	4	0.04	0.20	0.7
Bolt	Stainless steel	Virgin (0%)	0.05	1	0.05	0.25	0.8
Springs	Stainless steel	Virgin (0%)	0.08	3	0.24	1.19	4.0
Bulb	Silica glass	Virgin (0%)	0.03	1	0.03	0.06	0.2
Bulb holder parts	Brass	Virgin (0%)	0.12	3	0.36	1.28	4.3
Electrical cable	Cable	Virgin (0%)	0.07	1	0.07	0.48	1.6
Power supply	Power supply unit	Virgin (0%)	0.20	1	0.20	6.82	22.7
Total				**23**	**4.56**	**30.11**	**100**

*Typical: Includes 'recycle fraction in current supply'

Manufacture:

Component	Process	Amount processed	CO2 footprint (kg)	%
Aluminium shade	Rough rolling	0.12 kg	0.05	1.2
Brass shade cap	Rough rolling	0.05 kg	0.01	0.2
Aluminium supports	Extrusion, foil rolling	0.80 kg	0.58	15.4
Cast iron base	Casting	2.00 kg	1.58	41.6
Base cover	Rough rolling	0.30 kg	0.07	1.9
U-backet upright	Casting	0.30 kg	0.26	6.9
Pins	Extrusion, foil rolling	0.04 kg	0.05	1.2
Bolt	Extrusion, foil rolling	0.05 kg	0.06	1.5
Springs	Wire drawing	0.24 kg	1.03	27.1
Bulb	Glass molding	0.03 kg	0.03	0.8
Bulb holder parts	Extrusion, foil rolling	0.36 kg	0.08	2.2
Total			**3.80**	**100**

Transport:

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Sea	Sea freight	15467.00	0.80	92.7
Road	32 tonne truck	187.00	0.03	3.2
Delivery	Light goods vehicle	77.00	0.03	4.0
Total		**15731.00**	**0.86**	**100**

	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 1 year product life):	18.379

Hedge trimmer (mains) - Detailed breakdown of individual life

Material:

Component	Material	Recycled content*	Part mass	Qty.	Total mass (kg)	CO2 footprint	%
Motor part 1	Low carbon steel	Virgin (0%)	1.08	1	1.08	1.95	12.4
Motor part 2	Medium carbon steel	Virgin (0%)	0.38	1	0.38	0.68	4.3
Motor part 3	Cast iron, gray	Virgin (0%)	0.50	1	0.50	0.85	5.4
Motor part 3	Non age-hardening wrought Al-alloys	Virgin (0%)	0.34	1	0.34	4.47	28.3
Motor part 4	Copper	Virgin (0%)	0.25	1	0.25	0.93	5.9
Blades	High carbon steel	Virgin (0%)	0.50	2	1.00	1.80	11.4
Steel blade support	Medium carbon steel	Virgin (0%)	0.25	1	0.25	0.45	2.9
Gear	High carbon steel	Virgin (0%)	0.04	1	0.04	0.07	0.5
Electrical cable	Cable	Virgin (0%)	0.50	1	0.50	3.41	21.6
Plastic moulding	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.03	5	0.15	0.57	3.6
Screws self tapping	Stainless steel	Virgin (0%)	0.00	8	0.02	0.08	0.5
Plug	Plugs, inlet and outlet	Virgin (0%)	0.09	1	0.09	0.46	2.9
Terminal block	Plugs, inlet and outlet	Virgin (0%)	0.01	1	0.01	0.04	0.3
Total				**25**	**4.60**	**15.76**	**100**

*Typical: Includes 'recycle fraction in current supply'

Manufacture:

Component	Process	Amount processed	CO2 footprint (kg)	%
Motor part 1	Rough rolling	1.08 kg	0.22	12.8
Motor part 2	Rough rolling	0.38 kg	0.09	5.4
Motor part 3	Casting	0.50 kg	0.39	23.1
Motor part 3	Forging	0.34 kg	0.13	7.5
Motor part 4	Wire drawing	0.25 kg	0.28	16.3
Blades	Rough rolling	1.00 kg	0.26	15.2
Steel blade support	Rough rolling	0.25 kg	0.06	3.6
Gear	Casting	0.04 kg	0.03	2.0
Plastic moulding	Polymer molding	0.15 kg	0.23	13.6
Screws self tapping	Forging	0.02 kg	0.01	0.6
Total			**1.71**	**100**

Transport:

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Sea	Sea freight	15467.00	0.81	92.7
Road	32 tonne truck	187.00	0.03	3.2
Delivery	Light goods vehicle	77.00	0.04	4.0
Total		**15731.00**	**0.87**	**100**

	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 1 year product life):	6.294

Toaster (plastic) - Detailed breakdown of individual life phases

Material:

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	CO2 footprint (kg)	%
Body moulding	Polypropylene (PP)	Virgin (0%)	0.32	1	0.32	1.00	20.1
Base	Polypropylene (PP)	Virgin (0%)	0.18	1	0.18	0.56	11.3
Various mouldings	Polypropylene (PP)	Virgin (0%)	0.01	5	0.03	0.08	1.6
Toaster top	Stainless steel	Virgin (0%)	0.09	1	0.09	0.45	9.0
Screws	Stainless steel	Virgin (0%)	0.00	2	0.00	0.01	0.2
Various mouldings	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.00	4	0.01	0.03	0.5
Electronic assemblies	Printed circuit board assembly	Virgin (0%)	0.04	2	0.08	0.78	15.7
Various metal parts	Medium carbon steel	Virgin (0%)	0.03	17	0.43	0.77	15.5
Various AL parts	Non age-hardening wrought Al-alloys	Virgin (0%)	0.00	11	0.05	0.69	14.0
Mica substitute	Silica glass	Virgin (0%)	0.00	12	0.04	0.10	2.0
Heating element	Nickel-chromium alloys	Virgin (0%)	0.00	1	0.00	0.01	0.2
Cable	Cable	Virgin (0%)	0.01	1	0.01	0.07	1.4
Plug	Plugs, inlet and outlet	Virgin (0%)	0.08	1	0.08	0.42	8.5
Total				**59**	**1.32**	**4.95**	**100**

*Typical: Includes 'recycle fraction in current supply'

Manufacture:

Component	Process	Amount processed	CO2 footprint (kg)	%
Body moulding	Polymer molding	0.32 kg	0.51	47.2
Base	Polymer molding	0.18 kg	0.29	26.5
Various mouldings	Polymer molding	0.03 kg	0.04	3.7
Toaster top	Rough rolling	0.09 kg	0.05	4.9
Screws	Extrusion, foil rolling	0.00 kg	0.00	0.2
Various mouldings	Polymer molding	0.01 kg	0.01	1.0
Various metal parts	Rough rolling	0.43 kg	0.10	9.6
Various AL parts	Rough rolling	0.05 kg	0.02	1.8
Mica substitute	Glass molding	0.04 kg	0.05	5.0
Heating element	Wire drawing	0.00 kg	0.00	0.2
Total			**1.09**	**100**

Transport:

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Sea	Sea freight	15467.00	0.23	92.7
Road	32 tonne truck	187.00	0.01	3.2
Delivery	Light goods vehicle	77.00	0.01	4.0
Total		**15731.00**	**0.25**	**100**

	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 1 year product life):	14.960

Toaster (diecast metal) - Detailed breakdown of individual life

Material:

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	CO2 footprint (kg)	%
Side body casting	Zinc die-casting alloys	Virgin (0%)	0.75	2	1.50	6.15	47.9
Base casting	Zinc die-casting alloys	Virgin (0%)	0.60	1	0.60	2.46	19.2
Various mouldings	Polypropylene (PP)	Virgin (0%)	0.01	5	0.03	0.08	0.6
Toaster top	Stainless steel	Virgin (0%)	0.09	1	0.09	0.45	3.5
Screws	Stainless steel	Virgin (0%)	0.00	2	0.00	0.01	0.1
Various mouldings	Acrylonitrile butadiene styrene (ABS)	Virgin (0%)	0.01	4	0.02	0.08	0.6
Electronic assemblies	Printed circuit board assembly	Virgin (0%)	0.04	2	0.08	0.78	6.1
Various metal parts	Medium carbon steel	Virgin (0%)	0.05	17	0.85	1.54	12.0
Various AL parts	Non age-hardening wrought Al-alloys	Virgin (0%)	0.00	11	0.05	0.69	5.4
Mica substitute	Silica glass	Virgin (0%)	0.00	12	0.04	0.10	0.8
Heating element	Nickel-chromium alloys	Virgin (0%)	0.00	1	0.00	0.02	0.2
Cable	Cable	Virgin (0%)	0.01	1	0.01	0.07	0.5
Plug	Plugs, inlet and outlet	Virgin (0%)	0.08	1	0.08	0.42	3.3
Total				**60**	**3.36**	**12.84**	**100**

*Typical: Includes 'recycle fraction in current supply'

Manufacture:

Component	Process	Amount processed	CO2 footprint (kg)	%
Side body casting	Casting	1.50 kg	0.77	51.6
Base casting	Casting	0.60 kg	0.31	20.6
Various mouldings	Polymer molding	0.03 kg	0.04	2.7
Toaster top	Rough rolling	0.09 kg	0.05	3.6
Screws	Extrusion, foil rolling	0.00 kg	0.00	0.2
Various mouldings	Polymer molding	0.02 kg	0.03	2.1
Various metal parts	Rough rolling	0.85 kg	0.21	14.0
Various AL parts	Rough rolling	0.05 kg	0.02	1.3
Mica substitute	Glass molding	0.04 kg	0.05	3.7
Heating element	Wire drawing	0.00 kg	0.00	0.2
Total			**1.49**	**100**

Transport:

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Sea	Sea freight	15467.00	0.59	92.7
Road	32 tonne truck	187.00	0.02	3.2
Delivery	Light goods vehicle	77.00	0.03	4.0
Total		**15731.00**	**0.64**	**100**

Appendix S Embodied GHGs (kgCO_2e) for the most commonly repaired products

Rank	Item	Average product weight (kg)	Average embodied kg CO2e /kg	Product embodied kg CO2e
1	Laptop	2.5	122.2	304.2
2	Tablet (iPad)	0.7	392.4	287.8
3	Hi-Fi music system	6.9	27.0	186.5
4	Speakers	6.3	27.0	169.2
5	Bicycle pedal (non elec)	15.1	9.9	149.6
6	VCR cassette recorder	4.7	27.0	127.8
7	Microwave oven	9.8	13.0	127.4
8	Hi-Fi amplifier	4.5	27.0	121.5
9	Phone (DEC)	1.3	76.9	102.6
10	Dehumidifier	7.6	10.4	79.1
11	CD/DVD player	2.8	27.0	74.8
12	Food mixer/blender (elec.)	4.0	15.7	63.6
13	Curtains	2.9	20.7	60.3
14	Shredder (paper)	3.8	15.7	59.5
15	TV (LCD)	3.3	17.4	56.8
16	Camera (digital)	0.5	119.7	55.8
17	Clothes steamer	6.1	9.1	55.3
18	DAB/FM portable radio	1.6	27.0	43.4
19	Mower (electrical)	10.2	4.0	41.0
20	Blanket (quilt/duvet)	1.5	27.5	40.8
21	Smart phone	0.1	296.0	38.6
22	Hedge trimmer (elec.)	4.1	9.4	38.1
23	Tape/cassette recorder	1.4	27.0	37.8
24	Vacuum cleaner	6.3	5.9	37.0
25	Camera (modern 35mm)	0.6	63.4	35.7
26	Sewing machine	8.6	4.1	35.0
27	Pressure washer (elec.)	5.5	5.9	32.7
28	Kettle (elec.)	1.0	31.1	32.3
29	Printer	2.8	11.0	30.8
30	Drill (elec.)	1.7	15.7	26.7
31	Anglepoise Lamp	3.4	7.6	26.0
32	Razor (elec.)	0.6	38.0	23.8
33	Jacket (cloth)	0.8	28.3	22.8
34	Coat	0.8	26.9	20.9
35	Suitcase	4.1	4.8	20.0
36	Handbag	0.7	29.4	19.1
37	Table lamp (metal)	2.5	7.0	17.6
38	Coffee machine (elec.)	1.9	9.1	17.5
39	Trousers	0.5	32.9	17.3
40	Bag (cloth)	0.6	29.4	17.1
41	Standard lamp	4.4	3.8	17.1
42	Toy (soft)	0.5	31.0	16.8
43	Rucksack	0.8	21.1	16.6
44	Chair (mixed materials)	7.6	2.1	16.2
45	Lighting (decorative)	0.9	17.8	16.0
46	Cardigan	0.4	38.2	15.7
47	Fan (elec.)	1.4	11.3	15.6
48	Shoes	0.7	21.3	14.1
49	Dress	0.8	17.6	13.9
50	Table (wood/metal)	6.3	2.2	13.8
51	Clock (electronic)	1.3	10.2	12.8
52	Skirt	0.5	24.9	12.0
53	Jumper	0.4	30.5	11.1
54	Iron (steam)	1.2	9.1	11.0
55	Toaster (elec.)	2.3	4.6	10.6
56	Vacuum cleaner (battery)	1.9	5.3	10.1
57	Hair straightener/tongs	1.1	9.0	9.7
58	Electric heater/radiator	3.3	2.9	9.6
59	Table lamp (wood)	2.4	3.9	9.2
60	Loppers	1.2	6.9	8.1
61	Clock (mechanical)	2.0	4.0	7.9
62	Musical instrument (wood)	1.8	3.9	7.0
63	Shirt	0.2	25.6	6.4
64	Spade/fork (non powered)	1.3	4.5	5.9
65	Hairdryer	0.6	9.0	5.8
66	Toy (electronic/plastic)	0.8	7.1	5.8
67	Shears	1.1	5.0	5.4
68	Staple gun	0.8	5.4	4.1
69	Watch (battery)	0.2	23.3	3.9
70	Extension cable	0.6	5.9	3.7
71	Necklace	0.1	70.0	3.5
72	Ornament (china/glass)	1.1	3.0	3.3
73	Headphones (over-ear)	0.4	7.1	3.0
74	Torch (battery)	0.5	5.3	2.4
75	Secateurs	0.6	3.2	1.9
76	Glasses (specticals)	0.3	7.1	1.9
77	Brooch	0.1	18.1	1.7
78	Bracelet	0.1	18.1	1.4
79	Earrings (metal)	0.0	97.3	1.3

Appendix T Defra landfill (and recycling) GHGs displaced by completed repairs

No.	Product	Average product weight kg	Defra category for waste calc.	Defra Landfill kg CO2e/tonne	Defra Recycled kg CO2e/tonne	Defra total Landfill kg CO2e	Defra total Recyled kg CO2e	Number of successfully repaired items	Total weight kg	Defra total Landfill kg CO2e*	Defra total Recyled kg CO2e**
1	Anglepoise Lamp	3.44	WEEE - mixed	16.6	21.8	0.057	0.075	4	13.8	0.23	0.30
2	Bag (cloth)	0.58	Clothing	445.3	21.8	0.259	0.013	20	11.6	5.19	0.25
3	Bicycle pedal (non elec)	15.09	Metal: scrap metal	9.3	21.8	0.140	0.328	129	1,946	18.10	42.35
4	Blanket (quilt/duvet)	1.48	Clothing	445.3	21.8	0.661	0.032	4	5.9	2.64	0.13
5	Bracelet	0.08	Metal: scrap metal	9.3	21.8	0.001	0.002	14	1.1	0.01	0.02
6	Brooch	0.10	Metal: scrap metal	9.3	21.8	0.001	0.002	15	1.4	0.01	0.03
7	Camera (digital)	0.47	WEEE - mixed	16.6	21.8	0.008	0.010	1	0.5	0.01	0.01
8	Camera (modern 35mm)	0.56	Metal: scrap metal	9.3	21.8	0.005	0.012	6	3.4	0.03	0.07
9	Cardigan	0.41	Clothing	445.3	21.8	0.182	0.009	11	4.5	2.01	0.10
10	CD/DVD player	2.77	WEEE - mixed	16.6	21.8	0.046	0.060	24	66.5	1.10	1.45
11	Chair (mixed materials)	7.62	Metal: scrap metal	9.3	21.8	0.071	0.166	34	258.9	2.41	5.63
12	Clock (electronic)	1.26	WEEE - small	16.6	21.8	0.021	0.027	23	28.9	0.48	0.63
13	Clock (mechanical)	2.00	Metal: scrap metal	9.3	21.8	0.019	0.043	4	8.0	0.07	0.17
14	Clothes steamer	6.08	WEEE - mixed	16.6	21.8	0.101	0.132	4	24.3	0.40	0.53
15	Coat	0.78	Clothing	445.3	21.8	0.346	0.017	23	17.9	7.97	0.39
16	Coffee machine (elec.)	1.93	WEEE - small	16.6	21.8	0.032	0.042	7	13.5	0.22	0.29
17	Curtains	2.92	Clothing	445.3	21.8	1.299	0.063	11	32.1	14.29	0.70
18	DAB/FM portable radio	1.61	WEEE - mixed	16.6	21.8	0.027	0.035	82	131.7	2.18	2.87
19	Dehumidifier	7.60	WEEE - mixed	16.6	21.8	0.126	0.165	2	15.2	0.25	0.33
20	Dress	0.79	Clothing	445.3	21.8	0.352	0.017	20	15.8	7.04	0.34
21	Drill (elec.)	1.69	WEEE - mixed	16.6	21.8	0.028	0.037	15	25.4	0.42	0.55
22	Earrings (metal)	0.01	Metal: scrap metal	9.3	21.8	0.000	0.000	12	0.2	0.00	0.00
23	Electric heater/radiator	3.28	WEEE - mixed	16.6	21.8	0.054	0.071	13	42.6	0.71	0.93
24	Extension cable	0.63	WEEE - mixed	16.6	21.8	0.011	0.014	9	5.7	0.09	0.12
25	Fan (elec.)	1.38	WEEE - mixed	16.6	21.8	0.023	0.030	9	12.4	0.21	0.27
26	Food mixer/blender (elec.)	4.04	WEEE - small	16.6	21.8	0.067	0.088	24	97.0	1.61	2.11
27	Glasses (specticals)	0.27	Plastics: average plastics	9.3	21.8	0.002	0.006	5	1.3	0.01	0.03
28	Hair straightener/tongs	1.08	WEEE - mixed	16.6	21.8	0.018	0.024	8	8.6	0.14	0.19
29	Hairdryer	0.64	WEEE - mixed	16.6	21.8	0.011	0.014	13	8.4	0.14	0.18
30	Handbag	0.65	Clothing	445.3	21.8	0.289	0.014	22	14.3	6.37	0.31
31	Headphones (over-ear)	0.43	WEEE - mixed	16.6	21.8	0.007	0.009	8	3.4	0.06	0.07
32	Hedge trimmer (elec.)	4.08	WEEE - mixed	16.6	21.8	0.068	0.089	30	122.3	2.03	2.66
33	Hi-Fi amplifier	4.50	WEEE - mixed	16.6	21.8	0.075	0.098	10	45.0	0.75	0.98
34	Hi-Fi music system	6.91	WEEE - mixed	16.6	21.8	0.115	0.150	12	82.9	1.37	1.80
35	Iron (steam)	1.20	WEEE - mixed	16.6	21.8	0.020	0.026	15	18.1	0.30	0.39
36	Jacket (cloth)	0.81	Clothing	445.3	21.8	0.359	0.018	22	17.7	7.90	0.39
37	Jumper	0.37	Clothing	445.3	21.8	0.163	0.008	22	8.0	3.58	0.17
38	Kettle (elec.)	1.04	WEEE - small	16.6	21.8	0.017	0.023	12	12.5	0.21	0.27
39	Laptop	2.49	WEEE - mixed	16.6	21.8	0.041	0.054	28	69.7	1.16	1.52
40	Lighting (decorative)	0.90	WEEE - small	16.6	21.8	0.015	0.019	13	11.6	0.19	0.25
41	loppers	1.18	Metal: scrap metal	9.3	21.8	0.011	0.026	4	4.7	0.04	0.10
42	Microwave oven	9.77	WEEE - small	16.6	21.8	0.162	0.213	8	78.1	1.30	1.70
43	Mower (electrical)	10.17	WEEE - mixed	16.6	21.8	0.169	0.221	20	203.5	3.37	4.43
44	Musical instrument (wood)	1.78	Wood	819.1	21.8	1.461	0.039	6	10.7	8.76	0.23
45	Necklace	0.05	Metal: scrap metal	9.3	21.8	0.000	0.001	68	3.4	0.03	0.07

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Continued: Defra landfill (and recycling transportation) GHGs displaced by completed repair of product types

No.	Product	Average product weight kg	Defra category for waste calc.	Defra Landfill kg CO2e/tonne	Defra Recycled kg CO2e/tonne	Defra total Landfill kg CO2e	Defra total Recyled kg CO2e	Number of successfully repaired items	Total weight kg	Defra total Landfill kg CO2e*	Defra total Recyled kg CO2e**
46	Ornament (china/glass)	1.09	Glass	26.0	21.8	0.028	0.024	6	6.6	0.17	0.14
47	Phone (DEC)	1.33	WEEE - mixed	16.6	21.8	0.022	0.029	8	10.7	0.18	0.23
48	Pressure washer (elec.)	5.55	WEEE - mixed	16.6	21.8	0.092	0.121	3	16.6	0.28	0.36
49	Printer	2.81	WEEE - mixed	16.6	21.8	0.047	0.061	9	25.3	0.42	0.55
50	Razor (elec.)	0.63	WEEE - mixed	16.6	21.8	0.010	0.014	8	5.0	0.08	0.11
51	Rucksack	0.79	Clothing	445.3	21.8	0.350	0.017	14	11.0	4.90	0.24
52	Secateurs	0.60	Metal: scrap metal	9.3	21.8	0.006	0.013	9	5.4	0.05	0.12
53	Sewing machine	8.62	WEEE - mixed	16.6	21.8	0.143	0.188	49	422.2	7.00	9.19
54	Shears	1.08	Metal: scrap metal	9.3	21.8	0.010	0.024	6	6.5	0.06	0.14
55	Shirt	0.25	Clothing	445.3	21.8	0.111	0.005	25	6.2	2.77	0.14
56	Shoes	0.66	Clothing	445.3	21.8	0.294	0.014	7	4.6	2.06	0.10
57	Shredder (paper)	3.78	WEEE - mixed	16.6	21.8	0.063	0.082	4	15.1	0.25	0.33
58	Skirt	0.48	Clothing	445.3	21.8	0.215	0.011	18	8.7	3.87	0.19
59	Smart phone	0.13	WEEE - mixed	16.6	21.8	0.002	0.003	7	0.9	0.02	0.02
60	Spade/fork (non powered)	1.32	Metal: scrap metal	9.3	21.8	0.012	0.029	5	6.6	0.06	0.14
61	Speakers	6.27	WEEE - mixed	16.6	21.8	0.104	0.136	4	25.1	0.42	0.55
62	Standard lamp	4.44	WEEE - mixed	16.6	21.8	0.074	0.097	12	53.3	0.88	1.16
63	Staple gun	0.76	Metal: scrap metal	9.3	21.8	0.007	0.017	5	3.8	0.04	0.08
64	Suitcase	4.13	Plastics: PP (incl. forming)	9.3	21.8	0.038	0.090	4	16.5	0.15	0.36
65	Table (wood/metal)	6.30	Wood	819.1	21.8	5.162	0.137	12	75.6	61.94	1.65
66	Table lamp (metal)	2.52	WEEE - mixed	16.6	21.8	0.042	0.055	84	212.0	3.51	4.61
67	Table lamp (wood)	2.38	WEEE - mixed	16.6	21.8	0.039	0.052	9	21.4	0.35	0.47
68	Tablet (iPad)	0.73	WEEE - mixed	16.6	21.8	0.012	0.016	7	5.1	0.09	0.11
69	Tape/cassette recorder	1.40	WEEE - mixed	16.6	21.8	0.023	0.030	10	14.0	0.23	0.30
70	Toaster (elec.)	2.29	WEEE - small	16.6	21.8	0.038	0.050	26	59.6	0.99	1.30
71	Torch (battery)	0.46	WEEE - mixed	16.6	21.8	0.008	0.010	18	8.3	0.14	0.18
72	Toy (electronic/plastic)	0.81	WEEE - mixed	16.6	21.8	0.014	0.018	31	25.3	0.42	0.55
73	Toy (soft)	0.54	Clothing	445.3	21.8	0.242	0.012	8	4.3	1.94	0.09
74	Trousers	0.53	Clothing	445.3	21.8	0.234	0.011	109	57.3	25.50	1.25
75	TV (LCD)	3.27	WEEE - mixed	16.6	21.8	0.054	0.071	3	9.8	0.16	0.21
76	Vacuum cleaner	6.28	WEEE - mixed	16.6	21.8	0.104	0.137	60	376.5	6.24	8.19
77	Vacuum cleaner (battery)	1.92	WEEE - mixed	16.6	21.8	0.032	0.042	3	5.8	0.10	0.13
78	VCR cassette recorder	4.73	WEEE - mixed	16.6	21.8	0.078	0.103	4	18.9	0.31	0.41
79	Watch (battery)	0.17	WEEE - small	16.6	21.8	0.003	0.004	12	2.0	0.03	0.04
	Totals							**1,445**	**5,055**	**231**	**110**

Total kg of material diverted from landfill and recycling	Inc Bicycles	5,055		
	Ex Bicycles	3,109		
*Total diverted kg CO2e with UK landfill rate of 54.8%	Inc Bicycles		126.6	
	Ex Bicycles		108.9	
**Total diverted kg co2e with UK recycling rate of 45.2%	Inc Bicycles			49.7
	Ex Bicycles			7.7

**Note: Recycling figure only considers transportation and basic preparation of waste before recycling process. See Defra (2018)

*Note: Landfill emissions from material decomposition

Appendix U Breakdown of spares parts used for completed repairs (n=1014)

Description of replacement part	Frequency	Percent
Spare part not used	522	51.5
Re-stiching required	96	9.5
Small electrical connection repaired	54	5.3
Glued/screwed	34	3.4
Cleaning/removal of debris	27	2.7
Mains cable repair	27	2.7
Soldered repair	24	2.4
ZIP replacement	19	1.9
Product set-up required	15	1.5
Discrete electronic component	14	1.4
Drive belt replaced	14	1.4
Low voltage cable repaired	14	1.4
Battery replaced	13	1.3
Patch and stich	13	1.3
Fuse replaced	12	1.2
Lubrication (grease/oil)	12	1.2
Mains cable replaced	11	1.1
Bulb replacement	10	1
Small fixing required (nut/bolt)	10	1
Electrical connector - including mains plug	8	0.8
Mechanical switch	7	0.7
Button replaced (clothing)	7	0.7
Handbag clasp replaced	7	0.7
Clasp or catch (jewellery) replaced	6	0.6
Puncture repaired	6	0.6
Gear wheel replacement	5	0.5
Software reset/reconfiguration	3	0.3
Bicycle wheel spoke replaced	3	0.3
Light bulb holder replaced	3	0.3
Metal part (Jewellery)	2	0.2
Electrical motor bushes	2	0.2
Motor	2	0.2
Aerial replaced	2	0.2
Power supply - external	2	0.2
New electronic module or PCB	2	0.2
LCD screen replacement	1	0.1
Power supply - internal	1	0.1
Heating element replaced	1	0.1
Eyelet replaced	1	0.1
New plastic part <= 10grams	1	0.1
Metal part (small 10 grams)	1	0.1
Total	1014	100

Appendix V Breakdown of all spare parts use for all attempted repairs (n=1014)

Repair category	Reapir - spare part embodied kgCO2e	Completed Frequency	Completed Total kgCO2e	Partial Frequency	Partial Total kgCO2e	Not completed Frequency	Not completed Total kgCO2e	Advice given Frequency	Advice given Total kgCO2e
LCD screen replacement	3.960	0	0.00	0	0.00	1	3.96	0	0.00
Software reset/reconfiguration	0.000	3	0.00	0	0.00	0	0.00	0	0.00
Small electrical connection repaired	0.206	47	9.68	6	1.24	0	0.00	1	0.21
Product set-up required	0.000	13	0.00	1	0.00	0	0.00	1	0.00
Cleaning/removal of debris	0.000	23	0.00	3	0.00	1	0.00	0	0.00
Discrete electronic component	0.391	12	4.69	2	0.78	0	0.00	0	0.00
Mechanical switch	0.213	5	1.07	0	0.00	1	0.21	1	0.21
Soldered repair	0.000	21	0.00	1	0.00	2	0.00	0	0.00
Clasp or catch (jewellery) replaced	0.115	6	0.69	0	0.00	0	0.00	0	0.00
Metal part (Jewellery)	0.277	2	0.55	0	0.00	0	0.00	0	0.00
Electrical motor bushes	0.174	2	0.35	0	0.00	0	0.00	0	0.00
Drive belt replaced	0.529	9	4.76	5	2.65	0	0.00	0	0.00
Mains cable repair	0.000	25	0.00	1	0.00	1	0.00	0	0.00
Motor	4.830	2	9.66	0	0.00	0	0.00	0	0.00
Battery replaced	0.367	12	4.40	0	0.00	0	0.00	1	0.37
Filter (air) replaced	0.784	0	0.00	0	0.00	0	0.00	0	0.00
Low voltage cable repaired	0.000	11	0.00	2	0.00	0	0.00	1	0.00
Aerial replaced	0.671	2	1.34	0	0.00	0	0.00	0	0.00
Power supply - external	5.560	1	5.56	1	5.56	0	0.00	0	0.00
Power supply - internal	5.530	1	5.53	0	0.00	0	0.00	0	0.00
Fuse replaced	0.391	11	4.30	1	0.39	0	0.00	0	0.00
Electrical connector - including mains plug	0.571	8	4.57	0	0.00	0	0.00	0	0.00
Mains cable replaced	3.297	11	36.27	0	0.00	0	0.00	0	0.00
Heating element replaced	2.157	1	2.16	0	0.00	0	0.00	0	0.00
Glued/screwed	0.056	31	1.74	3	0.17	0	0.00	0	0.00
Eyelet replaced	0.012	1	0.01	0	0.00	0	0.00	0	0.00
Gear wheel replacement	0.194	3	0.58	2	0.39	0	0.00	0	0.00
ZIP replacement	0.348	16	5.57	2	0.70	1	0.35	0	0.00
Bulb replacement	0.277	8	2.22	2	0.55	0	0.00	0	0.00
New plastic part <= 10grams	0.235	1	0.24	0	0.00	0	0.00	0	0.00
Button replaced (clothing)	0.080	7	0.56	0	0.00	0	0.00	0	0.00
Patch and stich	0.075	11	0.83	2	0.15	0	0.00	0	0.00
Handbag clasp replaced	0.268	7	1.88	0	0.00	0	0.00	0	0.00
Re-stiching required	0.000	93	0.00	2	0.00	1	0.00	0	0.00
Puncture repaired	0.000	6	0.00	0	0.00	0	0.00	0	0.00
Bicycle wheel spoke replaced	0.268	2	0.54	0	0.00	1	0.27	0	0.00
Lubrication (grease/oil)	0.000	12	0.00	0	0.00	0	0.00	0	0.00
Small fixing required (nut/bolt)	0.028	7	0.20	3	0.08	0	0.00	0	0.00
Metal part (small 10 grams)	0.268	1	0.27	0	0.00	0	0.00	0	0.00
New electronic module or PCB	0.963	2	1.93	0	0.00	0	0.00	0	0.00
Light bulb holder replaced	0.186	3	0.56	0	0.00	0	0.00	0	0.00
Spare part not used	0.000	234	0.00	58	0.00	185	0.00	45	0.00
Totals		673	**112.68**	97	**12.65**	194	**4.79**	50	**0.79**

Total items presented for repair	1014
Total GWP kg CO2e	130.90
Total items completed	673
Resulting spares GWP kg CO2e per completed repair	**0.195**

Appendix W Independent t-test for number of items taken by visitors and volunteers

Group statistics
Number of items taken

Volunteer	N	Mean	Std. Deviation	Std. Error Mean
No	168	1.4	0.631	0.049
Yes	50	1.46	0.676	0.096

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Number of items taken	Equal variances assumed	0.751	0.387	-0.534	216	0.594	-0.055	0.103	-0.259	0.148
	Equal variances not assumed			-0.515	76.161	0.608	-0.055	0.107	-0.269	0.159

Appendix X Breakdown of transportation GHG emissions by vehicle and journey distance

	Petrol							Diesel								Hybrid	Electric	Other						
	Car type							Car type									Car type							
	Small economy car - (such as Nissan Micra, Ford Ka, Citroen C1)	Compact car - (such as Ford Fiesta, VW up!, Kia Picanto)	Mid-size car - (such as Ford Focus, VW Golf)	Full-size car - (such as Ford Mondeo, Vauxhall Insignia)	Luxury car - (such as BMW 5 series, Audi A8, Jaguar XJ)	SUV Sports Utility Vehicle (such as VW Tiguan, Ford Kuga, Toyota RAV4)	4x4 - (such as Range Rover, Land Rover, Volvo XC90)	Small economy car - (such as Nissan Micra, Ford Ka, Citroen C1)	Compact car - (such as Ford Fiesta, VW up!, Kia Picanto)	Mid-size car - (such as Ford Focus, VW Golf)	Full-size car - (such as Ford Mondeo, Vauxhall Insignia)	Luxury car - (such as BMW 5 series, Audi A8, Jaguar XJ)	SUV Sports Utility Vehicle (such as VW Tiguan, Ford Kuga, Toyota RAV4)	4x4 - (such as Range Rover, Land Rover, Volvo XC90)	Van - (such as Ford Transit, Renault Trafic)	SUV Sports Utility Vehicle (such as VW Tiguan, Ford Kuga, Toyota RAV4)	Small economy car - (such as Nissan Micra, Ford Ka, Citroen C1)	Bicycle	Bus	Train (overground)	Train (underground)	Mobility scooter (electric)	Walked	**Total CO2**
Total journeys	22	18	27	17	2	5	2	2	8	18	11	4	5	4	3	2	2	10	5	2	1	1	51	**222**
Total distance km	209.21	194.73	236.57	78.86	16.09	107.83	16.09	53.11	61.16	234.96	177.03	48.28	90.12	64.37	122.31	16.09	12.87	51.50	135.18	49.9	14.5	1.6	107.8	**2100.2**
Total kg CO2e	31.51	29.31	41.59	15.88	3.43	20.53	4.95	6.27	7.12	33.32	27.16	8.51	15.45	14.56	26.98	2.70	0.76	0.95	9.87	2.6	0.8	0.0	2.6	**306.9**
Total embodied kg CO2e	5.63	5.51	8.68	3.35	0.74	4.76	1.08	1.54	1.92	9.26	7.86	2.38	4.15	4.46	6.34	0.81	0.94							**69.40**

Average distance km **9.46**
Average kg CO2e **1.69**

Appendix Y Average financial donations per product repair

General area within UK for which donantions recorded	Number of products checked in for repair for which donations recorded	Total donations (£)	Average donantion for Repair Café sessions (£)
Midlands, England	21	138.7	6.60
Midlands, England	19	97.2	5.12
Midlands, England	15	80.5	5.37
Midlands, England	21	115.8	5.51
Midlands, England	22	111.1	5.05
Midlands, England	21	115.63	5.51
Midlands, England	40	215.23	5.38
Midlands, England	68	266.96	3.93
Midlands, England	33	158.05	4.79
Midlands, England	41	133.93	3.27
Midlands, England	24	69.63	2.90
Midlands, England	26	89.15	3.43
Midlands, England	41	175	4.27
Midlands, England	60	155.24	2.59
Midlands, England	45	183	4.07
South West England	26	58.55	2.25
South West England	37	64	1.73
Wales	156	192	1.23
Wales	301	410	1.36
Wales	267	424	1.59
Wales	279	582	2.09
Soith East, England	848	3319	3.91
Total	2411	Total Average	3.72

Appendix Z GHG sensitivity to Perceived spending (Ps) and Repair life extension period (Rl)

Repaired product's life extension period (Rl) as a fraction of original's design life

Perceived saving (Ps) spent as a result of visiting a Repair Café per completed repair (£)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
12	13	10	7	4	1	-2	-5	-8	-11	-14	-17	-20
11	12	9	6	3	0	-3	-6	-9	-12	-15	-18	-21
10	10	7	4	2	-1	-4	-7	-10	-13	-16	-19	-22
9	9	6	3	0	-3	-6	-9	-11	-14	-17	-20	-23
8	8	5	2	-1	-4	-7	-10	-13	-16	-19	-22	-24
7	7	4	1	-2	-5	-8	-11	-14	-17	**-20**	-23	-26
6	6	3	0	-3	-6	-9	-12	-15	-18	-21	-24	-27
5	4	2	-1	-4	-7	-10	-13	-16	-19	-22	-25	-28
4	3	0	-3	-6	-9	-11	-14	-17	-20	-23	-26	-29
3	2	-1	-4	-7	-10	-13	-16	-19	-22	**-24**	-27	-30
2	1	-2	-5	-8	-11	-14	-17	-20	-23	-26	-29	-32
1	0	-3	-6	-9	-12	-15	-18	-21	-24	-27	-30	-33
0	-1	-4	-7	-10	-13	-16	-19	-22	-25	-28	-31	-34
-1	-3	-6	-9	-11	-14	-17	-20	-23	-26	-29	-32	-35
-2	-4	-7	-10	-13	-16	-19	-22	-24	-27	-30	-33	-36

Resulting GHG emissions from one completed repair ($kgCO_2e$)

Assumptions: Product average embodied emssions of 33.3 $kgCO_2e$
Product life expectancy of 5.9 yrs
GHG intensity 1.23 $kgCO_2e$ / £ spent

Appendix AA Supervisor signed self-check ethics form

From: **University of Surrey** digital.platforms@surrey.ac.uk
Subject: Form submission from: FEPS Ethical Review Self-Check Form
Date: 3 November 2017 at 16:36
To: sp00497@surrey.ac.uk

Thank you for completing the "FEPS Ethical Review Self-Check Form." If all your answers to the questions were 'No", please print the results of your submission below, sign it and get your supervisor to sign it as well.

If this project does not require a Favourable Ethical Opinion, you must include this email in the appendix of your research report.

Submitted on Friday, November 3, 2017 - 16:36
Submitted by user: Anonymous
Submitted values are:

==Project details==
Student name: Stephen Privett
URN: 6330280
Email address: sp00497@surrey.ac.uk
Programme / course: MSc Sustainable Development
Supervisor: Professor Angela Druckman
Supervisor email address: a.druckman@surrey.ac.uk
Dissertation title: Potential impact of community repair activities on mitigation of greenhouse gas emissions in the U.K.
Project abstract (250 words):
Consumers in the developed world have become normalised to a culture of replacing goods once they become faulty with newly produced products, rather than repairing. This has increased raw material consumption and growth in energy intensive industries whose emissions contribute to increasing levels of anthropogenic greenhouse gases entering the atmosphere and forcing climate change.

Over the last decade voluntary community repair organizations such as Repair Café Foundation and Restart have encouraged consumers to repair household goods rather than dispose of them at municipal collection sites for landfill or recycling. Such organisations offer benefits to the community, including; providing a hub for social contact and networking, economic savings for consumers, skill sharing and reduced environmental impact from a reduction in landfill waste.

As the repair community grows and becomes more organised the need to share data, monitor progress and report information to the public in a meaningful and rigorous way has become more important. At present little work has been undertaken to accurately assess what effect community repair activity has now, and could have in the future on the mitigation greenhouse gas emissions.

The study aims to identify the types of products being repaired and the level of new product displacement taking place, potentially reducing manufacturing emissions. Further analysis of owner feedback to establish how product repair may increase use life, and alters consumption patterns, will also be considered to suggest offset factors needed to accurately quantify the impact of community repair activities on greenhouse gas emissions.

==Research participants==
Is the research proposal to be carried out by persons unconnected with the University, but wishing to use staff and/or students as participants? No
Does the study involve prisoners or young offenders? : No
Does the study involve children under 16 years or other vulnerable groups such as those 16 and over who may feel under pressure to take part due to their connection with the researcher? No
Do you plan to provide financial payments or payments in kind to participants above reimbursement for out of pocket expenses, provision of refreshments or entry into a low-value prize draw, or could the compensation amount to an hourly rate more than the minimum wage or more than £100 in total, or do you otherwise plan to offer incentives which may unduly influence participants' decision to participate? No
Are you investigating existing working or professional practices

among participants, identifiable to yourself as the researcher at the University of Surrey? No

==Research protocol==

Does the study involve any risk to a participant's health or well-being (for example intrusive or painful physiological or psychological procedures)? No

Could questioning – in questionnaire or in interview – or other methods used, cause offence, be distressing or be deeply personal for the target group? (This may include questions on sensitive data, i.e. ethnicity, political views, religion, physical or mental health/condition, sexual life/orientation and alleged offences): No

Does the research involve the new collection or donation of human tissue from a living person or the recently deceased according to the Human Tissue Authority? No

Does the research require participants to take part in the study without their knowledge and/or consent at the time (e.g. covert observations, emergency research)? No

Does the research involve deception other than withholding information about the aims of the research until the debriefing? No

Does the research involve activities where the safety/ wellbeing of the researcher may be in question (e.g. travel to potentially dangerous places)? No

Could the behavioural/physiological intervention possibly lead to discovery of ill health or concerns about wellbeing in a participant incidentally even if the intervention in itself causes no more than minimal stress is to the research participant? No

==Data protection==

Does the study involve access of records of personal or sensitive confidential information? No

Are you linking or sharing personal data or confidential information beyond the initial consent given (including linked data gathered outside of the UK)? No

Will you collect or access audio/video recordings, photographs or quotations within which participants may be identifiable and with the intention to disseminate those beyond the research team? No

Will you use identifiable information provided/held with the samples/data? (This also holds for samples/data that are not anonymised in a sufficiently robust way which might allow the researcher or others to identify whom the sample was obtained from).: No

The results of this submission may be viewed at:
https://www.surrey.ac.uk/node/118761/submission/446546

Supervisor : A. Druckman [signature] 7.2.18