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The Long View

Exploring Product Lifetime Extension

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Foreword

Less than nine months into 2016, we started consuming more resources than our planet produces over the whole year. Short use and fast replacement of products increasingly dictates consumption patterns in many regions. With the expected doubling of the global middle class in the coming years, the way we consume will have an ever-growing influence on the planet and its ability to support us. A transition to a more circular economy and to sustainable consumption and production practices is urgent to alleviate this situation.

This is recognized in the 2030 Agenda for Sustainable Development, which has the promotion of Sustainable Consumption and Production at its core. The 10-Year Framework of Programmes on Sustainable Consumption and Production provides the platform for this action. Under this mandate, the Consumer Information Programme - led by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany, the Ministry of Environment and Forestry of Indonesia, and Consumers International – supports ways to help consumers act on their sustainability intentions.

One of the Programme's objectives is to drive change in business and government by encouraging more sustainable product design and business models. Product lifetime extension makes a compelling case as it reduces resource use and waste, while preserving the economic value embedded in products.

The Consumer Information Programme, with support from the French Government, has therefore undertaken this study, published under the title of The Long View - Exploring Product Lifetime Extension, to analyse the optimal replacement moments of key products, and propose measures to be taken by the private sector, governments and consumers, to extend the useful life of products.

I would like to thank the French Government for commissioning this study, and for providing valuable insight and experience on this important topic. We hope that the report's recommendations will help policy makers worldwide to set enabling conditions for companies and consumers to take action. With support from the Consumer Information Programme and its network, UN Environment will continue to encourage effective practices and help enable all stakeholders to 'take the long view' on product design and use.

Ligia Noronha
Director, Economy Division
UN Environment

Foreword

The list of products we buy and own gets longer and longer. Advertising, design, fashion and technological change invite us to replace more frequently our goods: furniture, clothes, electrical and electronic appliances etc.

This faster turnover carries consequences for the environment: more and more raw materials are extracted, more and more products are made and brought to the consumers, and in the end, more and more waste must be managed. Today, this linear consumption pattern, which takes place not only in developed countries but also in emerging economies now, is associated with unsustainable pressures for the environment and the ecosystems.

We shift towards a long term perspective and lean against the dominant wind of excessive use and waste of resources that characterise our production and consumption patterns. A momentum is now at work and initiatives are multiplying; public action must stimulate and boost this change.

In two recent strategic laws (Consumption Law in 2014, and Energy Transition for Green Growth Law in 2015), France paved the way for an extension of products' lifetime. We aim to act both on production (fight against planned obsolescence) and on consumption (information on the availability of spare parts, extension of consumer rights in the legal guarantees of conformity, and display of product lifetime).

More precisely, on the production side, the 2015 law adopted an official definition of planned obsolescence and introduced a penalisation of this practice.

On the consumption side, it is striking to see how little information is available to the consumer on product lifetime, notably concerning mass-market products. This often pushes him/her to choose cheap products, due to the lack of visibility on the quality of products that can sometimes be more expensive, but that last longer. Correcting this information asymmetry constitutes a step for progress towards a better balanced market, thus allowing to enhance repairable and longer-lasting products.

The extension of product lifetime results in a reduction of waste and in resource saving. It is a major component of the transition towards a more circular economy. It also appears among the tools promoted by two UN programmes in which France is deeply involved: the Sustainable Development Goals, with ODD 12 (responsible consumption and production), and the 10 Year Framework of Programmes on Sustainable Consumption and Production (10YFP).

In this context, the present study comes at a very timely moment for underpinning public policies aiming at better producing, better consuming and better informing. Therefore I warmly welcome this publication by UN Environment as it will contribute to raising the global awareness of the strategic dimension of this issue both for developed and developing countries.

Laurence Monnoyer-Smith
General Commissioner for Sustainable Development

Ministry for Ecological and Solidary Transition, France

Summary : The Long View
Exploring Product Lifetime Extension

The aim of this study is to provide recommendations on the opportunities available to consumers, the private sector and governments, of developed and developing economies, to address product lifetime extension. The primary focus of the report is on policy-making.

Through product lifetime extension, the rate at which we use up (natural) resources and produce waste can be radically reduced, while the economic value embedded in our products is preserved as much as possible. This is, in theory, a win-win situation for both the environment and the economy (businesses save on costs and consumers get better value for money). The report investigates several ways to extend the useful lives of products: (1) by simply using products for a long(er) time, (2) by extending their use through design, maintenance and upgrades, and/or (3) by recovering broken products through repair, refurbishment or remanufacturing.

A state-of-the-art review in the first chapters concludes that product lifetime extension is not a widespread practice in developed economies. Here, rapid replacement cycles have become the norm and consumers express feeling "locked-in" to wasteful consumption patterns. In developing and lower-income economies, the situation is different as informal repair markets are common and there seems to be a culture of keeping products in use for longer.

Replace or Repair? Literature review

A review of Life Cycle Assessment (LCA) studies was conducted on the optimal replacement moment of seven use-intensive product categories (washing machines, refrigerators, TVs, mobile phones, laptops, clothing and vacuum cleaners). The results show that washing machines and refrigerators should be used for at least 10 years before they should be replaced with a more energy-efficient model. Vacuum cleaners, clothing, mobile phones and laptops are usually replaced 'before their time' and should be (re)used for longer (although pinpointing an exact replacement moment is very difficult). In the case of TVs, it makes sense to keep older LED models in use, instead of replacing them with newer, less energy efficient 4K models. It follows that each product category requires a specific approach and set of policy measures as illustrated in the table on the next page.

In general, policy makers should bear in mind that: 1) Successive generations of electronic products are not always more energy efficient, 2) Replaced products are not always taken out of circulation, and 3) LCA scenarios must be modelled as close to the 'real, messy world' as possible to do justice to the highly diverse user contexts and cultures. This requires large amounts of data, both technical (i.e. energy efficiency developments) and sociological (i.e. diverse use patterns).

Main findings from the literature	Recommendations
Washing machines should be at least 10 years old before replacement becomes worthwhile (from an environmental perspective). There is a bias towards European data. Data from developing economies is missing. Consumer use scenarios and use contexts vary greatly across cultures, which impact the optimal replacement moment.	• Develop more Life Cycle Assessment studies that include a range of use patterns in order to arrive at more reliable conclusions. • Promote sustainable use practices to help decrease the environmental impact of clothes washing (for instance cold water washing, or completely filling the machine before washing).
Based on data of developed economies, refrigerators of over 10 years old should be replaced with more energy efficient models. Old refrigerators are however not always taken out of circulation, but often exported to developing economies, where they continue to be used.	• Raise awareness and build capacity on energy-efficient repair in developing economies.
Energy consumption of the latest generations of TVs (UHD, smart) is increasing compared to previous generations of LED TVs. Product replacement could thus undo energy savings which were made in the past. With such rapid technology cycles in the television industry, LCA studies on optimal replacement moments quickly become irrelevant.	• Ensure that the energy consumption of novel generations of TVs does not trend upward again, through appropriate measures in policies, such as the European Ecodesign Directive.
The extraction and manufacturing phases are still the biggest contributors to the environmental impact. The impacts of the use phase are increasing, however, due to the increasing use of network infrastructure.	• Incentivise the extension of the useful life of mobile phones beyond the current 3-4 years, for instance through stimulating refurbishment or modular/repairable designs. • Consider regulating the energy consumption of the network infrastructure, to ensure it keeps functioning energy efficiently.
Product lifetime extension leads to environmental benefits. The optimal replacement moment was calculated to be (at least) 7 years. In practice, laptops are used for 4 years on average. Even though laptops are becoming more lightweight, this does not necessarily change their environmental impact.	• Ensure that the lifetime of laptops is extended, for instance through minimum durability criteria, and stimulating modular/repairable designs.
Vacuum cleaners are often replaced before they are 5 years old. This is less than the expected lifespan. Product lifetime extension is recommendable in most cases. In spite of the minimum durability criteria in the EU Ecodesign Directive, there may be factors that stimulate rapid replacement of vacuum cleaners. One of these factors is a seeming reluctance (in developed economies) to engage in maintenance and repair activities, instead preferring to buy a new (cheap) vacuum cleaner.	• Pay attention to consumer education. • Stimulate better product design (easier to clean and repair).
Extending the useful life of clothes (including greater re-use) and more sustainable laundry practices have the potential to create considerable resource and cost savings.	• Create durability indicators on clothing. • Stimulate new business models (such as leasing or hiring of clothes). • Educate consumers regarding sustainable laundry practices.

Recommendations for developed economies

For developed economies, the report describes two policy perspectives related to product lifetime extension. The open source perspective is based on the idea that if consumers have better information, they can make better buying decisions. The success of the open source policy perspective will depend on consumers taking action, supported by relevant policy measures, non-governmental organizations (NGOs) and industry initiatives. The report recommends the following short/medium-term policy measures:

	Open Source perspective: enable and support consumers to extend the lifetime of their products
Law against planned obsolescence	Planned obsolescence was recently made punishable by law in France (through articles L441-2 and L454-6 of the Code de la Consommation). It is recommended to evaluate the implementation of the French law and, if effective, to consider EU-wide adoption and adoption in other countries/regions.
Minimum durability criteria	The European Ecodesign Directive already has minimum durability criteria for light bulbs and vacuum cleaners, and more measures are planned. The criteria in the European Ecodesign Directive could be extended and measurement standards, test standards and verification methods for durability and resource efficiency could be developed for a range of products.
Product lifetime labelling	A comprehensive study by the European Economic and Social Committee (2016) indicates that consumers respond positively to product lifetime labelling. More research and testing needs to be done to study the effectiveness of lifetime labels, and to develop standardized measurement procedures. If product lifetime standards are based on manufacturers' data, they have to be willing to participate, thus incentives need to be introduced.
Extended product warranty	France and Portugal have extended the period for the reversal of the burden of proof from 6 months to two years. It is recommended to evaluate the French and Portuguese measures and, if successful, to consider making this an EU-wide measure and introducing it in other countries/regions.
Right to Repair legislation	Repair needs to be affordable and accessible for consumers (for instance through publicly available repair manuals). A reduction of Value Added Tax on repair can further incentivize actions in this area. In France, manufacturers and retailers are obliged to inform consumers on spare part availability. It is recommended to evaluate the 2016 law (decree nr. 2014-1482) and, if effective, to consider adoption at EU level and introduction of similar legislation in other countries/regions.
Monitoring of trends in product lifetimes	Monitoring the trends in product lifetimes of a range of energy-use-intensive products consistently, over a number of years, can track the impact from different generations of products and provide up-to-date suggestions for lifetime extension.
Consumer education and information	The promotion of the development of (for instance) product buying/use guides, or consumer awareness/marketplace campaigns, can increase the understanding of product durability, induce a positive consumer attitude towards product maintenance and repair, and encourage consumers to hold companies to account.

The second policy perspective is called closed loop. It is based on the idea that product lifetime extension is a strategic business decision. To 'close the loop' is for companies to (be able to) maintain economic control over their resources and products over the product's entire lifetime, including the consumer use stage, through alternative business models (like lease or pay-per-use). This incentivizes the development of durable and reusable products. The success of this perspective will depend on the extent to which these alternative business models are accepted and embraced by both consumers and industry. The report recommends the following short/medium-term policy measures:

	Closed Loop perspective: enable manufacturers to retain full responsibility over their products in order to extend product lifetime
Individual Producer Responsibility	Individual Producer Responsibility (IPR) can be considered for selected product categories. It is recommended to evaluate the Japanese IPR regulation for air conditioners, TVs, refrigerators and washing machines, and to explore if a translation to other countries' contexts is feasible.
Removal of legal barriers for refurbishment and remanufacturing	The development of international standards for remanufacturing and the introduction of warranties and a tax reduction on remanufactured products can provide incentives. There is also a need to address trade barriers that prohibit the import of product parts that are to be remanufactured.
Alternative business models	Stimulating the acceptance of alternative business models (the shift from ' owning' to 'using' products) in the Business-to-Consumer market, includes addressing privacy and other liability issues pro-actively.

Recommendations for developing economies

For developing economies in which the informal second-hand and repair market is highly developed, the report recommends the following policy measures:

	Product lifetime extension in developing economies
Improvement of waste treatment infrastructure	In many economies a formal, environmentally sound and safe waste management system is needed. In order to make such a system function properly, public education on how and where to dispose products is required.
Recognition of the full potential of the informal sector	Informal economic sectors that revolve around trading, repairing and regaining materials from redundant products currently lack access to investment capital and information to make repairs energy efficient, safe and environmentally sound. It is recommended to recognize these professions and offer them social rights, official status, and training.
Stimulation of energy efficient repair and refurbishment of old appliances	Addressing the often prevailing lack of an institutional infrastructure to implement energy efficiency regulations, appliance efficiency in the used and rehabilitated appliance market can for instance be promoted and increased through training and the provision of energy efficiency repair manuals.
Consumer education and information	The introduction of energy efficiency labelling, other eco-labels and awareness campaigns can stimulate the more affluent households to invest in high-quality, longer lasting and/or energy efficient products.
Monitoring, verification and enforcement (MVE) measures	Developing monitoring, verification and enforcement (MVE) measures can help ensure that energy efficiency and product lifetime standards are met.

Recommendations for the 10YFP Consumer Information Programme

Specific recommendations for the Consumer Information Programme of the 10 Year Framework of Programmes for Sustainable Consumption and Production (10YFP) to pursue include to:

- Work with consumer organizations to develop product buying and use guides in different economies, and/or include lifetime extension criteria in product testing and reviews.

- Create/promote awareness raising campaigns about 'buying for life'.

- Collect and promote innovative business practices (e.g. showcasing the shift to service models) through interactive formats, such as videos or social media. An emphasis should be put on sharing such practices between countries, and to feature leading cases from developing economies.

- Cooperate with knowledge institutes and universities to collect data on the real-life use of products in both developed and developing economies.

- Integrate consumer information components focusing on product lifetimes in existing e-learning courses.

The 10YFP Consumer Information Programme

The Consumer Information Programme of the 10 Year Framework of Programmes on Sustainable Consumption and Production acts as a global platform supporting the provision of quality information on goods and services, to engage and assist consumers in sustainable consumption. To do so, it implements and supports projects; undertakes research; identifies and encourages policies; and provides collaboration opportunities.

More information can be found at http://www.scpclearinghouse.org/consumer-information-scp.

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George Alexander Ishida Newman, 2014 (Flickr)

1. Introduction

1.1 Background: the need for product lifetime extension

On August 8, 2016, we began to use more from nature than our planet can renew in the whole year. "Earth overshoot day"[1] comes earlier every year. A major reason for this is the economic model of industrialized economies, referred to as the 'throughput' economy, or a 'take-make-dispose' economy; an economy that relies on large quantities of cheap, easily accessible materials and energy, and that produces vast amounts of waste (Ellen MacArthur Foundation, 2013). Another reason is that in many economies the average income is increasing, resulting in growing domestic consumption and generation of waste. According to the Organisation for Economic Cooperation and Development (OECD), sales of refrigerators, television sets, mobile phones, motors and automobiles have surged in virtually every African country in recent years. In Ghana, for instance, the possession of cars and motorcycles has increased by 81% since 2006 (Pezzini, 2012).

With the expected doubling of the global middle class in the coming years, it is widely recognized that the linear economic model is reaching its physical and environmental limits, and a transition to a more circular economy and to more sustainable consumption and production practices will make sense for people and the planet. In a circular economy, the value of products is maintained for as long as possible, for instance by extending their useful lives (EU, 2015).

There are several ways to extend the useful lives of products: (1) by simply using products for a long(er) time, (2) by extending their use through maintenance and upgrades, and/or (3) by recovering broken products through repair, refurbishment or remanufacturing (Den Hollander, 2017). The focus in this report is on all these forms of product lifetime extension. The report does not consider recycling, as this breaks down a product into its constituent materials and product integrity is lost. Through product lifetime extension, the rate at which we use up (natural) resources and produce waste is radically reduced, while at the same time the economic value embedded in our products is preserved as much as possible. In theory, this is a win-win situation for both the environment and the economy.

1.2 Objectives and questions

The objective of the study is to provide recommendations on the opportunities available to consumers, private sector and governments of developed and developing economies to address product lifetime extension. The following questions are addressed in the study:

1. **To what extent have product lifetimes been decreasing in industrialized societies?** This question focuses on evidence for decreasing product lifetimes from the scientific literature.

2. **Why is product lifetime extension not happening yet?** Given the overwhelming evidence from environmental scientists that our current linear economic system needs to change, why are rapid product replacement rates still the norm in industrialized societies?

3. **When does product lifetime extension make sense from an environmental life cycle perspective?** In other words, what are the optimal replacement moments for a number of selected products? The report reviews products with a dominant environmental impact in the use phase (energy and/or water consumption). The research on product lifetime extension shows that this is the most controversial group of products, as timely replacement by more energy efficient products could result in less environmental impacts than product lifetime extension.

4. **What product-specific policy measures and opportunities for product lifetime extension** follow from the conclusions of Question 3?

5. **What general opportunities and measures for product lifetime extension**, for governments, manufacturers and consumers from both developed and developing economies, follow from the answers to Questions 1-4, the scientific literature and expert interviews?

Zhao! 2012 (Flickr)
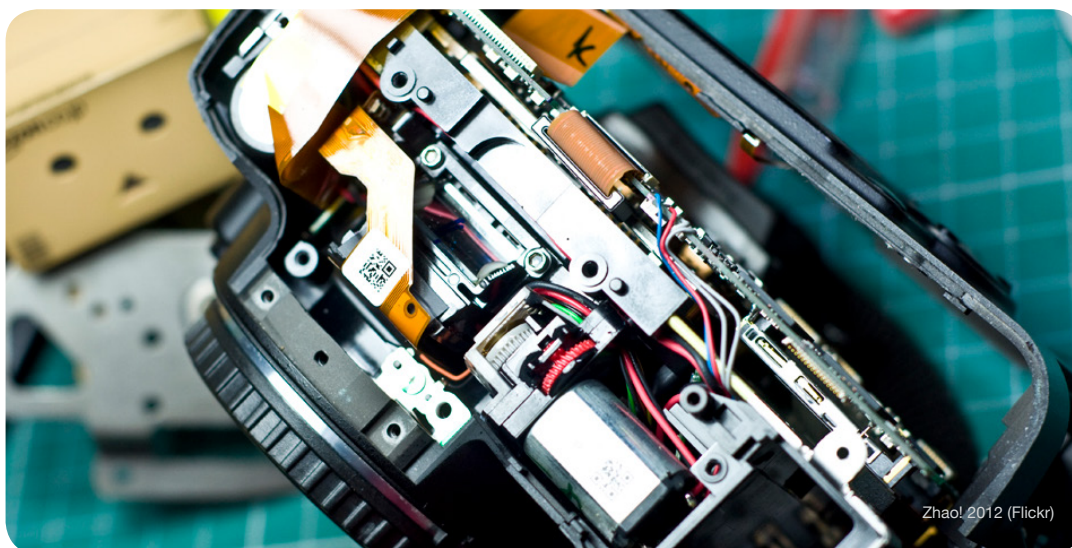
1.3 Definitions

Product lifetime and product lifetime extension

At some point in time, all products end their life and become obsolete. The term 'obsolescence' is often associated with negative ideas, while it simply means "the condition of no longer being used or useful."[2] This can be for objective reasons, for instance when the product physically breaks down and is beyond repair, or for subjective reasons, when the user does not like or want the product anymore (for instance because it no longer meets the user's needs, or because the perceived costs of maintenance or repair are too high). It happens regularly that perfectly functional products are discarded (Oswald and Reller, 2011). This report acknowledges that product lifetime is not solely determined by the physical properties of the product, but also by subjective reasons that cause a product's life to end (Den Hollander, 2017). The definition was written from the perspective of a single user.

> **Product lifetime**: the duration of the period that starts at the moment a product is released for use after manufacture or recovery, and ends at the moment a product becomes obsolete.

In order to prolong or extend product lifetime, designers have three design approaches at their disposal (Den Hollander, 2017). The first approach focuses on long(er) use of a product (longer than the market average), the second on extended viability of a product (through maintenance and repair), and the third on product recovery (including its components). These are explained in more detail below and in figure 1.1.

Designers can design products with an intrinsically long life through creating emotionally and/or physically durable products. This is referred to as 'resisting obsolescence'. Designers can also keep a product from becoming obsolete ('postponing obsolescence'), for instance through designing for maintenance and upgrading. The third design approach is to return an obsolete product to a non-obsolete state (also called recovery, or 'reversing obsolescence'), for instance through design for repair or remanufacturing. The definition for product lifetime extension follows logically from this description (Den Hollander, 2017):

> **Product lifetime extension** is the postponement or reversal of the obsolescence of a product through deliberate intervention.

The three design directions and approaches available to designers to prolong or extend a product's lifetime are summarized in figure 1.1 (Den Hollander, 2017).

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[2]Definition retrieved from http://www.merriam-webster.com/dictionary/obsolete
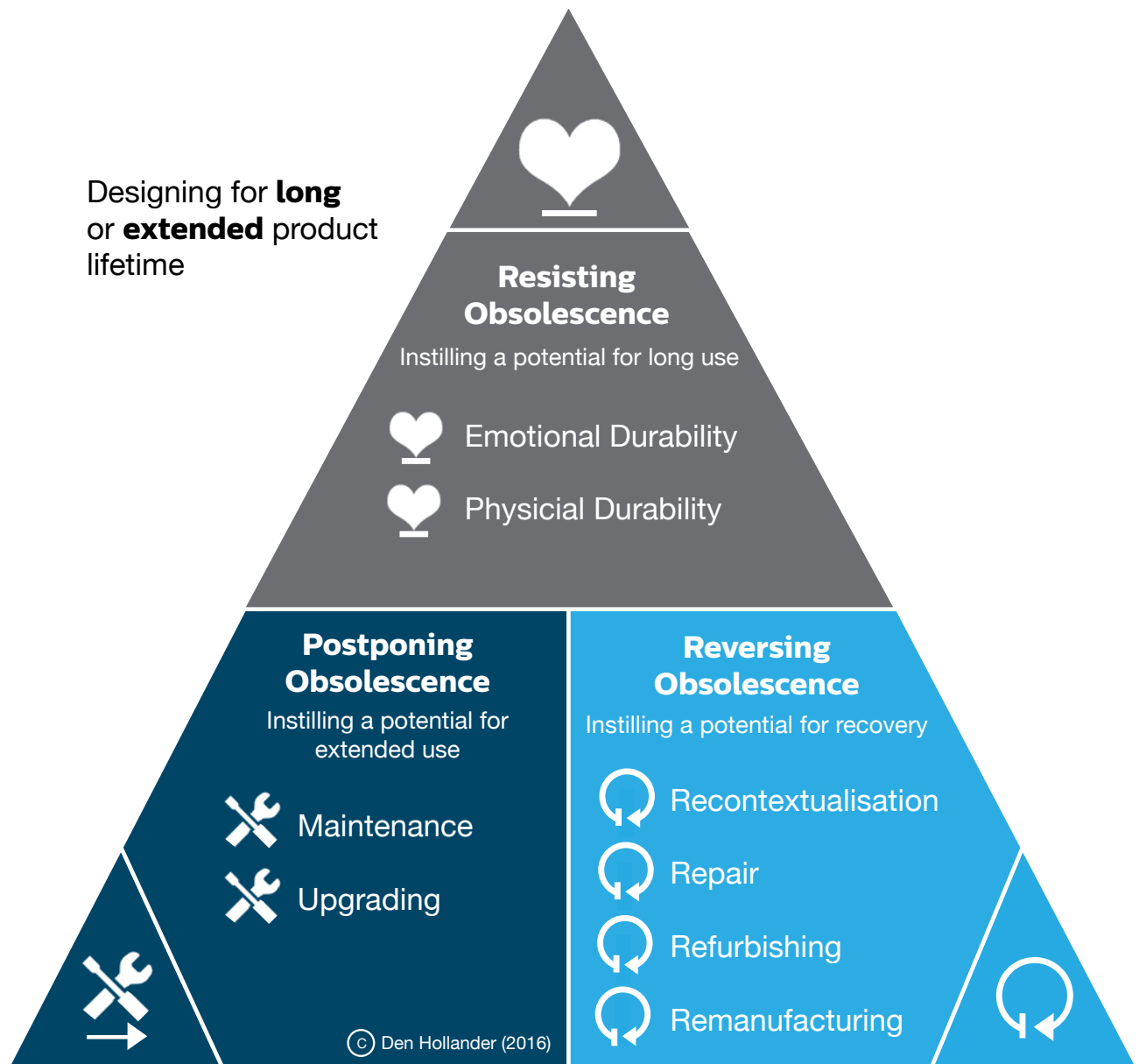
Figure 1.1 Different design directions and approaches for long or extended product lifetime

The least known intervention is 're-contextualizing', which is defined as "reuse of a product or its constituent components by a different user or owner and/or in a different role than it was originally designed to perform." (Den Hollander, 2017). In this definition, all changes to factors other than the actual product as it was designed are considered changes in 'context'. This could for instance be: a change in user or owner, or the reuse of a product for a different purpose (for instance, a wine bottle becomes a flower vase).

Although the overview in figure 1.1 was written from a designer's perspective, it can be useful in the context of this study because product lifetime is often associated with physical durability only. This overview shows there are at least seven other strategies to consider when discussing product lifetime and product lifetime extension.
Finally, it is important to note that recycling is not part of the scope of this report. Recycling inevitably leads to the loss of a product's integrity. Through recycling, some materials can be recovered, but the product as a whole is inevitably destroyed.

Developed and developing economies

This report will distinguish between developed and developing economies, whilst recognizing that the group of developing economies is highly diverse, and dynamically developing. The focus in this report is mainly on gross national income as a way to distinguish between different kinds of developing economies.

PICNIC Network, 2012 (Flickr)

1.4 Scope and Method

In order to answer research question 3 "When does product lifetime extension make sense from an environmental perspective?," a review of various product life cycle assessment (LCA) studies was undertaken. An LCA study gives insight into the environmental impact of a product through its life cycle stages: material extraction, production, transport, use and disposal. LCA studies in this context can compare scenarios of different product lifetimes based on their quantitative impacts, to identify the optimal replacement moment of products (so that minimal environmental impact is generated). From a product lifetime and environmental perspective, products can be divided into three categories:

- Disposable products with an intrinsically short life. Lifetime extension does not seem realistic here. Many fast-moving consumer goods are part of this category, for instance toilet paper or food packaging.

- Products that require no or minimal consumption of water, electricity or detergents, etc. during use, such as furniture and non-electric tools. Product lifetime extension should always be considered here because the biggest environmental impact comes from the production or disposal phases; and extending a product's life will lower the relative contribution of these phases.

- Resource-intensive products (during use). These are products that consume electricity, water, detergents, etc. during use, such as washing machines. Here, the question is whether reducing the use-phase impacts through the development of, for instance, more energy efficient products is more beneficial from an environmental perspective than product lifetime extension (ADEME, 2016). In other words: when should products in this third category be replaced, and when should they be repaired? What is their optimal replacement moment?

These questions are the topic of chapter 3 'Optimal replacement moment'.

Zhao!, 2010 (Flickr)

Selected use-intensive products

Seven products were selected for further review. These form a representative selection of diverse lifetime expectancies by consumers in the UK (Cox et al., 2013) and Brazil (Echegaray, 2016). Washing machines and refrigerators represent the 'workhorse' category, also described as products that are purchased for prolonged use (WRAP, 2013) and are usually only discarded when broken (Cox et al., 2013). TVs, mobile phones and laptops represent the 'up-to-date' products, known as products that are often replaced before they break (Cox et al., 2013) and are frequently upgraded to the latest technology. To represent products that are even more prone to short use cycles, a case study on clothing ('fast fashion') is done in which washing and drying is included in the system boundaries. Finally, vacuum cleaners are analysed because of the existing requirements regarding durability of the hose and motor life in the European Eco-design directive (Blepp, 2013), providing a case study of a product where product lifetime extension instruments are already in place.

	0–2 years	3–4 years	5–6 years	7–10 years	10+ years
In UK	Electric tooth-brush **Mobile phone** **Clothing** Shoes	Kettle MP3 Player Toaster **Computer** Cushions Suit	Camera Landline-phone Lamp Power tools **Vacuum-cleaner** **Washing-machine** Microwave Curtains	**TV** **Fridge/freezer** Cooker Sofa Carpet Bed	Boiler Kitchen units Wardrobe
In Brazil			Printer **Computer** Camera **Mobile phone**	Oven **Washing-machine** **Television** Microwave	**Fridge/freezer**

*Case-study products are marked in bold text

Figure 1.2 Lifetime expectancies based on UK (Cox et al., 2013) and Brazilian data (Echegaray, 2016)

Methods

This report is based on literature review and expert interviews. No original research (for instance first-hand consumer surveys to investigate product lifetimes, or life cycle assessment) was done. This report therefore mainly collates existing data and insights. Expert interviews were conducted to uncover opportunities to address product lifetime extension. Finally, the report collects insightful state of the art examples of policies and private sector initiatives regarding product lifetime extension.
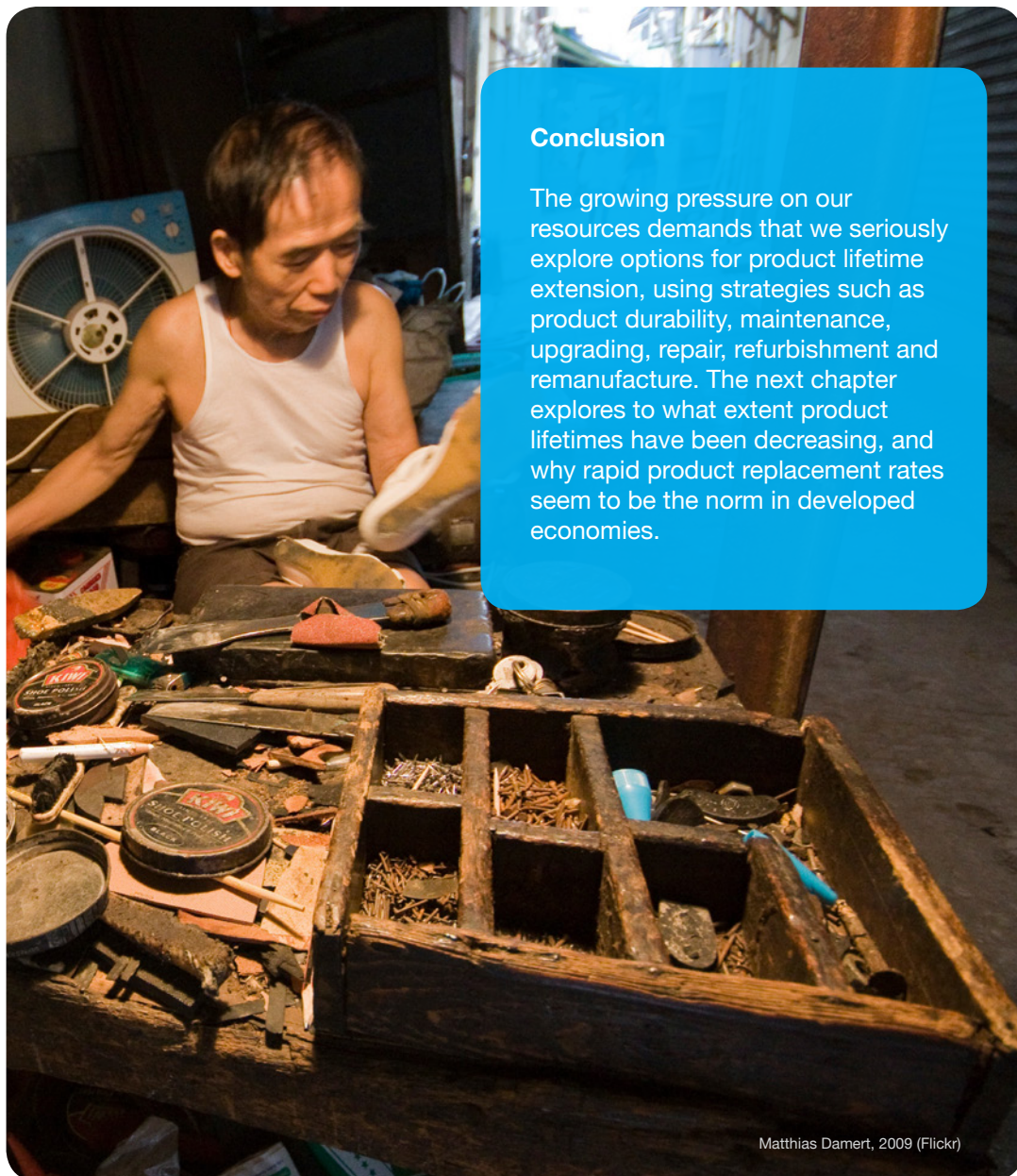
Conclusion

The growing pressure on our resources demands that we seriously explore options for product lifetime extension, using strategies such as product durability, maintenance, upgrading, repair, refurbishment and remanufacture. The next chapter explores to what extent product lifetimes have been decreasing, and why rapid product replacement rates seem to be the norm in developed economies.

Matthias Damert, 2009 (Flickr)

2. Our products do not last

The introduction briefly touched upon the complexity of product lifetime extension. Recently, the debate on planned obsolescence resurfaced. But did the lifetime of products really decrease and why are rapid product replacement rates still the norm?

2.1 Evidence of decreasing product lifetimes

Empirical evidence of trends in product lifetimes or replacement rates of consumer durables is difficult to find in the scientific literature. Bakker et al. (2014) showed that the median lifespan of most domestic appliances and consumer electronics has declined slightly between 2000 and 2005, based on Dutch data collected by Wang et al. (2013). The lifespan of mobile phones for instance decreased from 4.8 to 4.6 years (-3%), washing machines from 12.1 to 11.7 years (-3%), laptops from 4.3 to 4.1 years (-5%) and small consumer electronics from 9.4 to 7.4 years (-20%). In this study, lifespan was defined as the period from the moment a product was placed on the market, to the point where it was discarded through the Dutch municipal waste system.

A study commissioned by Germany's main environmental protection agency, the Umweltbundesamt, on the useful lifetime of products showed that the first useful service life of most consumer products (large and small appliances, consumer electronics and ICT equipment) has decreased over the last years (Prakash et al., 2016). The first useful service life is defined as the period a product is used by its first user. For large household appliances, for instance, first useful service life declined from 14.1 years in 2004 to 13.0 years in 2012/13. The study found out that an increasing share of appliances is replaced or disposed of before they reach an average first useful service life of 5 years.

Based on the few available studies, there is some empirical evidence of decreasing product lifetime (in developed economies). Prakash et al. (2016) conclude that the causes of obsolescence are highly varied, and "thus pinpointing any one specific cause is difficult" (p.5). Among the many causes listed are "deficient mechanical and electronic robustness", "software-induced reasons" (including peripheral devices becoming obsolete), "high cost of repair", and "trends and desire for new functionalities" (including socio-demographic factors such as moving to a new apartment).

2.2 Planned obsolescence

Planned obsolescence is generally described as a deliberate action by manufacturers and designers to shorten a product's lifetime in order to increase its replacement rate, at the expense of consumers. Guiltinan (2009) tries to explain how planned obsolescence came about, by pointing to the highly competitive global business environment. This has resulted in "systems that demand growth in output because the technologies amplify economies of scale and scope which can only be realized through faster product replacement and increasing consumption of products…" (Guiltinan, 2009, p. 21). In 2013, the European Economic and Social Committee (EESC) called for a total ban on the business strategy of planned obsolescence. As its justification, the EESC cited "numerous products that are designed to stop working within two or three years of their purchase – shortly after the expiry of their guarantee", and called for companies to make goods easier to repair through, for example, the supply of replacement parts; and consumers to be given better information about a product's estimated life expectancy (see http://www.eesc.europa.eu/?i=portal.en.ccmi-opinions.26788).

2.3 Consumer responses to short product lifetimes

Focusing only on manufacturers and designers is, however, not sufficient to explain planned obsolescence. Consumers are part of the economic system as well, and researchers have found that replacement buying behavior is complex. Rapid replacement cycles have, more or less, become the norm for consumers everywhere in the world, and have become part of the fabric of everyday life (Echegaray, 2016). Cooper (2004) finds there is little evidence that product durability (of household appliances) is a key consumer buying motive. And Guiltinan (2009) reports that consumers find it difficult to deny the benefits of prospective upgrades of products, for instance when these offer improved technological features.

There is however also evidence that consumers think products do not last as long as they should. Echegaray (2016) reports that 66% of 806 Brazilian respondents feel that product lifespans fall short of what they deem to be reasonable. Cooper (2004) finds that 45% of 802 British households were of the opinion that their household appliances do not last as long as they would like. Wieser et al. (2015, p. 390) find, based on a survey with over 1000 Austrian residents, that the respondents "want products to last considerably longer than they are currently used." In all cases, a wide range of products was studied (clothes, consumer electronics, appliances and furniture).
In contrast to the above findings, in a UK study by WRAP (2013) the majority of

respondents said they were satisfied with how long fridges, washing machines, vacuum cleaners, televisions and laptops last. And a study among 1075 German households indicated that the average lifespan for washing machines, laptops, kettles, TVs and hand mixers are close to the time when expectations of the consumers are 'almost fulfilled' or even 'met' (Hennies and Stamminger, 2016). Hennies and Stamminger (2016, p. 82) conclude: "This result is remarkable, because it could mean that manufacturers are able to engineer appliances to fulfil a specific lifespan just to meet expectations. However, does this mean that the lifespan can never exceed the expectations, and how were the expectations manifested in consumers' minds?" Wieser et al. (2015, p. 390) offer a possible answer: "Our interviews show that people generally assume that products will last considerably shorter than they would like them to last. For instance, one interviewee stated: I want a washing machine to last 10 years, but expect 5 years." Wieser et al (p. 392) theorize that: "Once a product has met one's expectations, it is 'mentally written off', and these low expectations may be used as justifications for early replacements."

Whether or not product lifetimes meet consumers' expectations, it is still the question whether consumers may take an active role in addressing product lifetimes. The dominant current consumer reaction seems to be one of disengagement or disinterest. In a study with twelve qualitative discussion groups, involving 115 consumers, Cox et al. (2013, p. 25) conclude: "Many in the groups felt powerless to behave any differently or exert pressure on producers even if they wanted to. They reported they often feel locked into frequent upgrades because of the speed of new technologies coming onto the market, combined with not wanting to be seen as 'old fashioned'." Echegaray (2016, p. 200) argues that "consumers may recognize that product durability has decreased (which is a true reflection of their own experience, if comparing past lifetime and projected lifespan of devices owned) and may wish products to last longer, but these orientations do not reflect their own management of product lifetime." And: "Admittedly, the critical issue of corporate responsibility for the deliberate design of products and campaigns to kindle product obsolescence and substitution is often met by consumer apathy." Echegaray (2016, p. 200) concludes: "…it is unlikely that public opinion will spur politicization of the obsolescence issue through boycotts, direct protests or support for new regulations." And Wieser et al. (p. 392) point to a "widespread belief that built-in obsolescence is ubiquitous", with consumers "blaming the capitalist system" (and thus taking a passive stance).

In at least one study, it appeared that consumers seldom connect product lifetimes to environmental problems. Cox et al. (2013, p. 25): "Few participants expressed any guilt around the volume of resource consumption this model implies and almost none had thought about the environmental impacts. Even when prompted, many participants struggled to see the connection between consumption and environmental problems." Breaking out of such powerful "lock-in" effects will require effective policy measures to support consumers and consumer organisations in addressing the current 'throw-away' culture.

2.4 Conclusion

There is limited empirical evidence that the lifetime of a range of consumer products has been decreasing over the past decades (in developed economies), therefore more research needs to be done to support the evidence base. Many researchers and commentators agree that product designers and manufacturers must take greater responsibility for developing durable products, and certainly avoid the practice of 'planned obsolescence'. They can also assist consumer choice by providing better information on the lifetime of their products. However, simply pointing towards industry and designers as the instigators of planned obsolescence is shortsighted. In other words, it is not possible to establish a clear cause-effect relationship when discussing decreasing product lifetime. Consumers also have a role to play, and their apparent dissatisfaction with the lifetime of their products has so far not translated into meaningful action. In fact, many researchers discuss 'consumer apathy' when it comes to addressing product lifetime. It follows that solutions are needed that engage and address consumers, and all other relevant actors in society, including policy makers.

It should be noted that this conclusion is mainly relevant for developed economies, where rapid replacement cycles have become a normal part of life. Empirical data on product lifetimes in developing economies is still absent from the literature. In general, developing economies with a higher gross national income show similar patterns of consumption as developed economies (Echegaray, 2016). In lower income economies, the situation is very different. This will be explored in more detail in the following chapters.

3. Optimal replacement moment

The optimal replacement moment is defined as the point in time where the environmental impacts that arise from using a product equal the embedded impacts of a (more energy efficient) replacement product (Bakker et al., 2014). In essence, the optimal replacement moment asks: should we repair this product, or should we replace it with a newer, more efficient version?

3.1 Introduction

Looking at energy-use-intensive products from a sustainability perspective, the question is whether to focus on timely replacement with more efficient models, or to extend the lifetime of the existing product (through, for instance, repair). In other words, what can the scientific literature tell us about the optimal replacement moment? Life Cycle Assessment studies for the seven selected use-intensive products were reviewed in an attempt to determine the optimal replacement moment.

3.2 Washing machines

Washing machines are considered as 'workhorse' products, as they are typically purchased for a lifetime of heavy and prolonged use (WRAP, 2013) and are usually only replaced when they break down completely or cannot be repaired at reasonable cost (Stamminger et al., 2005). This makes washing machines interesting – it may well be that keeping an old washing machine in operation is not the best strategy from an environmental perspective. What is the optimal replacement moment for washing machines?

LCA studies and the optimal replacement moment

Washing machines are use-intensive products that consume energy, water and detergents. The use phase contributes the most to the overall environmental impact of washing machines: 65% - 80%, depending on the environmental indicators used (Rüdenauer et al., 2005). Due to the improvements in efficiency during the use phase (for instance, sensor technology), a modest shift of environmental impacts towards the production phase can be seen.

Rüdenauer et al. (2005) determined the optimal life span of an average German washing machine using Life Cycle Assessment. Their functional unit was described as "the amount of laundry that is washed and dried in 22 years, in a household of 3 people." They conclude (p. 83): "The question if it is 'worth' to further use an existing washing machine or to substitute it and use a new model cannot be answered absolutely." Based on their assumptions, a washing machine needs to be at least 10 years old in order to justify replacing it with a more efficient model.

Based on the data assembled by Rüdenauer et al. (2005), Ardente and Mathieux (2014) analyze whether it is environmentally beneficial to extend the average lifetime of a washing machine (11.4 years) through repair by 1 to 4 years. They conclude that lifetime extension "can produce some environmental life-cycle benefits (such as the abiotic depletion potential), even if it would delay replacement with more energy-efficient products. However, the achieved benefits are variable, mostly depending on the selected impact category, the extension of the lifetime, the impacts of repair and the efficiency of the replacement product." (p. 71)

WRAP (2010) focusses on step-change improvements in the energy efficiency of washing machines. Their study shows that when replacing a washing machine, environmental savings can only be achieved when replacing A or C-rated machines with A+ or A++ machines (EU, 2010). Substituting to a washing machine class A++ would for instance lead to a reduction in energy consumption of about 22% (Ardente and Mathieux, 2014). It follows that replacement is only 'worthwhile' if there is a step-change in efficiency improvements.

Stamminger et al. (2005, p. 124) arrive at comparable conclusions. They found that the performance of washing machines has increased over time, making it difficult to compare old washing machines with newer models: "to achieve the same performance as a modern machine does by washing at 40 C, a 15-year-old machine must use a temperature of 60 C. A 15-year-old machine uses approximately twice as much energy and water to achieve the same performance as a new one." The authors recommend timely replacement of old machines, but do not give a specific optimal replacement moment.

In conclusion, there is a clear bias towards European data when it comes to assessing the environmental impacts and optimal lifetimes of washing machines. Data from developing economies is missing. The reviewed studies imply that a washing machine should be at least 10 years old before replacement becomes worthwhile, and that the new model should have a significantly higher energy efficiency than the old model. Much depends on the assumptions used by the researchers (for instance regarding the use scenario and LCA data), the system boundaries (e.g. the inclusion of clothes drying) and the rate of efficiency improvement of new washing machines.

Variations in use and use context across cultures

As the optimal replacement moment is defined as the point in time where the environmental impacts that arise from using a product equal the embedded impacts of a (more energy efficient) replacement product, it follows that the optimal replacement moment will vary considerably with varying uses and use contexts. In China, for instance, manual laundry washing is common in households that own a washing machine. Chinese households therefore consume less water with washing machines operations because of the low number of wash cycles. Japanese households commonly use cold water impeller-type washing machines. In contrast, European households perceive hot water as more hygienic, resulting in the use of drum type washing machines with hot water, which consume significantly larger amounts of electricity compared to the cold-water impeller type (Kim et al., 2015). The 'I prefer 30' campaign in Europe (http://www.iprefer30.eu/en) presents to consumers the environmental benefits of washing at 30 degrees, alongside the cost saving benefits of reduced electricity use and less damage to clothes.

Washing operations vary by household income, dwelling size, work patterns, electricity price, sources of electricity generation, perception of cleanliness (Kim et al, 2015); user behaviour such as the load, temperature of washing, the number of cycles (Rüdenauer et al., 2005); and washing technology such as horizontal or vertical axis washing machines (Pakula and Stamminger, 2009). Even the types of garments, how garments are placed in the machine and how they mix during the cleaning process result in a large degree of variability in the washing performance (WRAP 2010) and thereby influence the environmental impact of the use phase indirectly. For example, starting from 2005 an increase in the number of quick drying clothes has been recorded in Japan. These types of clothes can reduce CO_2 emissions by roughly 10% (Yamaguchi et al., 2011).

Besides this, the way washing machine innovations are incorporated into everyday life can negate potential energy savings. For instance, the average rated capacity of washing machines in Europe has grown from 5.0 kg in 2003 to 7.5 kg in 2014, a rise of 50%, while in the same period the average European household size has reduced from 2.4 to 2.3 people (Schmitz et al., 2016). A consumer survey among 5000 participants in eleven EU countries showed that the larger capacity is appreciated, but not always utilized. In fact, it seems that "consumers do not put more laundry into their bigger washing machines, but wash (almost) the same amount of laundry independent of the washing machine's rated capacity." (Schmitz et al., 2016, p. 232). This can result in higher energy and water consumption as washing machines work most efficiently at maximum load conditions.

Conclusion

Consumer use has a significant role to play in the environmental impact of washing machines, which varies greatly across regions and cultural contexts. However, it has not been investigated what impact different consumer use patterns have on the lifetime of washing machines, and how this may be addressed by targeted consumer information in order to find optimal washing machine replacement moments.

3.3 Refrigerators

A refrigerator is generally never turned off during its lifetime, making it a typical use-intensive product. According to Michel et al. (2015, p. 8), "refrigerators have improved a lot in the 20 years since the first Energy Label in Europe was introduced: the least efficient refrigerators on today's market are nearly 60% more efficient than the 1994 average". As energy efficiency has improved over time, what is the optimal replacement moment for refrigerators?

LCA studies and the optimal replacement moment

A study in Thailand found that replacing a 1997 refrigerator model with a 2003 model was environmentally attractive (Kiatkittipong et al., 2008). The authors conclude that in the case of continuously running products, timely replacement may be in order. They also note, however, that the possibility of easy upgrades with a low energy (use phase) consuming part might change the evaluation results and lead to an extended refrigerator lifetime.

Kim et al. (2006) looked at the optimal household refrigerator replacement moment from both an environmental and an economic perspective, based on USA data. Their models show that current owners should replace refrigerators that consume more than 1000 kWh/year of electricity (typical mid-sized 1994 models and older) as an efficient strategy from both cost and energy perspectives.

A study of Tasaki et al. (2013), based on Japanese data, showed that it was preferable to replace refrigerators after 8-10 years of use, even if the replacement product was 100 liters larger. And a study of Bakker et al. with UK data, indicated that refrigerators bought in 2001 should be replaced after 10 years, but given the recent energy efficiency improvements, refrigerators bought in 2011 should be used for 20 years instead of the average of 14 years (Bakker et al., 2014).

Based on data from these developed economies it can be concluded that, given the advances in energy efficiency, the 'older' refrigerators (10 years or older) should be replaced with new, highly energy efficient models. For these new models, a longer life than the average of 14-15 years (Bakker et al., 2014, Michel et al., 2015) may be desirable, both from an environmental and an economic perspective. As refrigerators run continuously, the optimal replacement moment is less dependent on variations in use scenarios (compared to for instance washing machines). It should be noted however that refrigerator performance deteriorates over time due to aging of insulation foam, but it is difficult to estimate this effect due to a lack of large-scale field data (Kim et al., 2006).

A final point of concern is that (according to Norwegian survey data among 1025 respondents) new energy efficient refrigerators tend not to replace older products, but are added to the present appliance population (people would put their old fridge in the garage and use it as an extra fridge, for instance). This was true for at least 68% of the refrigerators in the study sample. On the short term this may contribute to increased energy consumption for cooling (Strandbakken, 2009). Strandbakken adds (p. 149): "…understanding the sustainability impacts from the introduction of improved technologies becomes rather complicated and unpredictable when we move from technical-economic models into 'messy' social reality…".

Situation in developing economies

This 'messy' social reality (Strandbakken, 2009) regarding refrigerators can also be seen in developing economies. More than half of the refrigerators sold in Ghana, for instance, are old, used appliances which were shipped from Europe (Van Buskirk et al., 2007). Refrigerator energy use can be substantially higher in Africa than in developed economies, because of (1) higher ambient temperature and humidity, (2) the prevalence of old, used and poorly reconditioned refrigerators, (3) more intensive use of refrigerators for productive and commercial activities and (4) voltage and power supply fluctuations and inefficient use patterns as a result of these fluctuations (Van Buskirk et al., 2007, quoting Cornut, 2005).

Product lifetime extension (through repair and refurbishment) is widely practiced by informal repair shops in Ghana and in many other developing economies. According to Van Buskirk et al. (2007, p. 2405), "the informal sector may rehabilitate, rebuild and reuse appliances for many years after initial manufacture. This presents a distinct challenge for rapid efficiency improvements because it may take decades for higher efficiency products to propagate through the largely informal used and rebuilt appliance markets."

In most developing economies, the topic of product lifetime extension is therefore, in essence, a non-topic. High-value products such as consumer electronics and household appliances are reused and repaired for many years. From an environmental perspective, the real challenge is not how to prolong product lifetime, but how to improve the efficiency of appliances. According to Van Burskirk et al. (2007), the lack of an institutional infrastructure to implement energy efficiency regulations is one of the key problems. One of their suggestions is to promote and increase refrigerator efficiency in the used and rehabilitated fridge market, for instance through training and the provision of refrigerator efficiency rehabilitation/repair manuals (Van Buskirk et al., 2007).

Conclusion

This short literature review leaves us with a few uneasy questions. What if the discarded, inefficient European fridges are not recycled, but continue to live long and inefficient lives in another country and context, thus adding to the worldwide stock of refrigerators? What, in this context, is the value of LCA studies to determine optimal replacement moments? Are such studies perhaps framed too narrowly, providing us with a technical-economic model that ignores the many different uses and use contexts of the products under study?

3.4 Televisions

The past decade has seen a rapid succession of innovations in TV technology, replacing the old CRT (cathode ray tube) TVs with cold cathode fluorescent lamp (CCFL) technology, and later LED backlit TVs. This brought great advances in energy efficiency, with LED TVs 20% to 30% more efficient than CCFL backlit TVs (Park et al., 2011). "Even though televisions became steadily bigger and brighter and offered higher resolution over the past decade, energy consumption continuously declined." (NRDC, 2015). What is the optimal replacement moment for televisions?
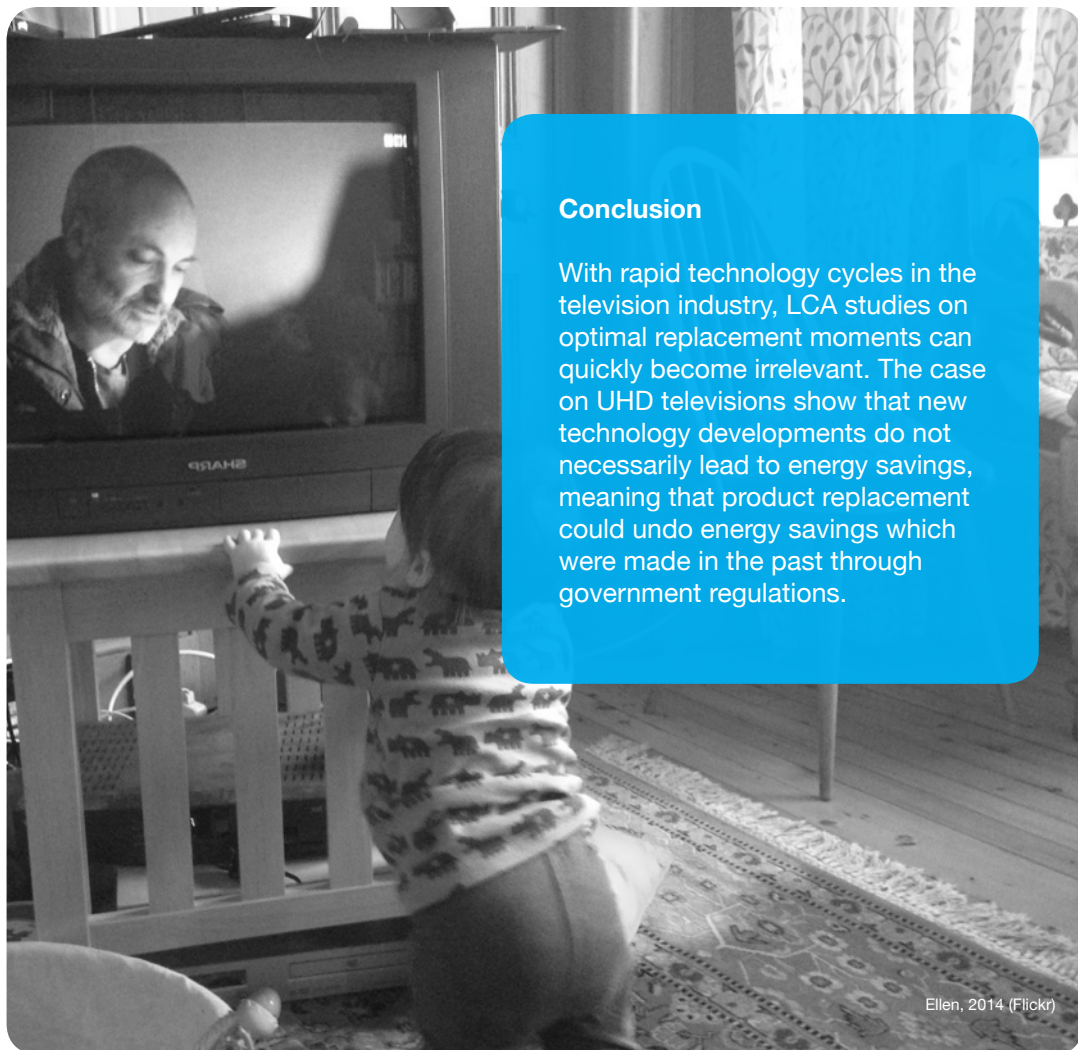
LCA studies and the optimal replacement moment

In 2003, Chalkley et al. (2003) estimated the optimal replacement moment for televisions between 11 and 13.2 years, but admitted to not having a reliable set of historical energy consumption data. Tasaki et al (2013) investigated replacement scenarios of a 28-inch CRT TV with a new flat panel TV (LCD of plasma) with 2008 data. Their analysis showed that the optimal replacement moment was after 8 to 10 years of use, provided that the screen size of the new TV was the same. Replacement with a display 10 inches larger was not preferable. TV watching time is also an important parameter. Tasaki et al. calculated that consumers who watch TV for 2.6 hours/day or less (which is considered 'not often'), should keep their old TVs instead of replacing them with a more efficient model. It should be noted that Chalkley et al. (2003) and Tasaki et al. (2013) did not take into account the more recent LED TV models. The energy savings achieved by LED TVs would likely have changed their findings.

Trends in TV technology

A recent NRDC report (2015) concludes that the period of declining energy consumption of TVs is however coming to an end. Manufacturers are increasingly using 'smart' or internet-connected capabilities in the new television models, which adds energy consumption, for instance when the TV is streaming content and browsing the internet. Also, there is a trend towards 4K models (which offer up to four times the resolution of a HD TV) and larger screens (NRDC, 2015). Average screen size has increased by 20% from 2007 to 2013 (King and Ponoum, 2011). As a result, energy use of TVs is pushed upwards again, both in active and in low-power modes. A test by NRDC (2015) with 21 55-inch televisions of 2014 and 2015 indicates that ultra-high-definition televisions use 30% more energy than HD models of the same size. Improvements to the energy efficiency of UHD and 4K TVs are still in their infancy stage, with only a 4% reduction in the energy use of 2015 models compared to similar-sized 2014 models (NRDC, 2015).

These recent negative trends in TV energy efficiency will impact the optimal replacement moment. The NRDC puts this in perspective: "If all televisions larger than 36 inches would shift to 4K television models of today, residential energy bills in America would rise by more than $1 billion per year and add an extra 4 million metric tons of CO2 emissions per year. As display modes, screen brightness, feature selections and room lighting can significantly affect energy use, user behavior is more important than ever." (NRDC, 2015, p. 31)

Conclusion

With rapid technology cycles in the television industry, LCA studies on optimal replacement moments can quickly become irrelevant. The case on UHD televisions show that new technology developments do not necessarily lead to energy savings, meaning that product replacement could undo energy savings which were made in the past through government regulations.

Ellen, 2014 (Flickr)

3.5 Mobile phones

The mobile phone has been one of the most disruptive technologies to personal connectivity (Suckling and Lee, 2015) and is constantly evolving (Prunel et al., 2014). The mobile network is getting more efficient with the transition from 2G to 4G networks. Mobile phones are becoming multifunctional with computer features such as navigation, gaming, etc. Displays are becoming larger with higher resolutions, and subsequent phone generations have more powerful microprocessors and more available memory (Prunel et al., 2014). In short, the mobile phones that are used today have a larger ecological footprint (Prunel et al., 2014) and their impact increases with each successive generation (Suckling and Lee, 2015). What is their optimal replacement moment?

LCA studies and the optimal replacement moment

Even though mobile phones are used intensively, a comparative study of Suckling and Lee (2015) indicates that in ten out of eleven LCA studies performed between 2005 and 2014 the 'extraction and manufacturing phase' contributes to more than half of the total CO_2 emissions, and hence the environmental impact, of a mobile phone. Yu et al. (2010) arrived at a similar conclusion in a LCA study of mobile phones in China that indicates that manufacturing accounts for 50% of the total energy consumption, followed by the use-phase of mobile phones which accounts for 20% of the total energy consumption. Under the assumption that mobile phones are, over time, becoming increasingly more resource efficient, Frey et al. (2006) calculated that it is ecologically better to keep and maintain a phone for at least 7 years if annual resource savings are above 20%, and for about 10–12 years if resource savings are at a 10% improvement rate.

In a more recent study, Suckling and Lee (2015) show however that the environmental impact of mobile phones may be increasing over successive generations, because of the increased use of network services (i.e. cloud-based services, streaming media) and associated infrastructure (servers, etc). Including the networks in the system boundary of a mobile phone LCA, Suckling and Lee (2015) calculated that the impact of the use phase doubled, with the other phases (extraction & manufacturing, distribution, end-of-life) not showing significant change. Prunel et al. (2014) who compared the impacts of a classic phone with no internet access, a multimedia phone with 2G network connections and a smartphone with 3G network connections confirm that these successive generations of mobile phones and accompanied user profiles lead to higher environmental impacts in the use phase.

The relatively short lifetime of mobile phones (according to Suckling and Lee, 2015, most LCAs assume a lifetime of 3 years) results in the 'extraction and manufacturing phase' still being the biggest contributor to the environmental impact of mobile phones, although the impact of the use phase is increasing. It can thus be argued that product lifetime extension is a recommendable strategy from an environmental perspective.

Replacement reasons for mobile phones

The lifespan of mobile phones is primarily driven by higher functionality offered in newer versions, rather than the functional lifespan of the device (Yu et al., 2011). Pricing and mobile phone features are important decision making factors. The business model of service providers also reinforces consumers to switch phones (Yu et al., 2012), which is illustrated by a survey in the United States and Canada in which 37 of 79 respondents stated that contracts that include 'free' phones or discounts are a primary or secondary reason for buying a phone (Huang and Truong, 2008). Also, the issue of older product models not supporting recent software upgrades has been mentioned as a reason for rapid replacement of electronic devices.[3]

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[3] http://www.beuc.eu/documents/files/FC/durablegoods/articles/0614_Which_UK.pdf
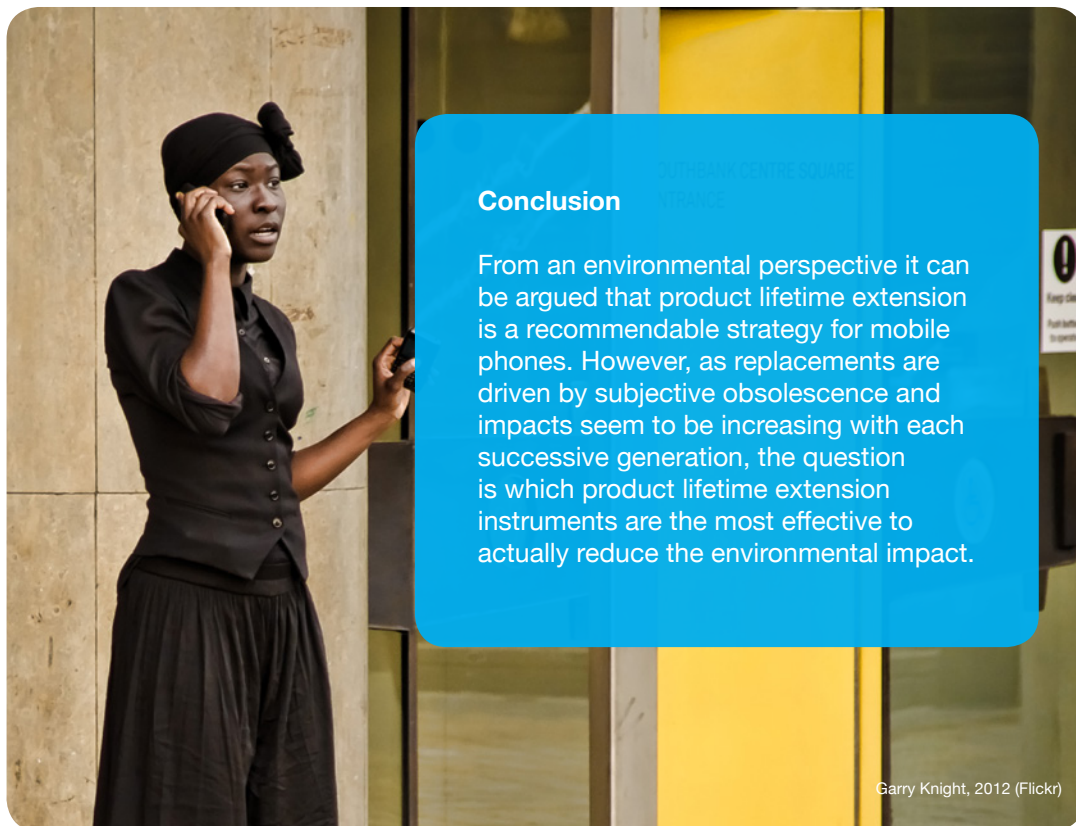
Conclusion

From an environmental perspective it can be argued that product lifetime extension is a recommendable strategy for mobile phones. However, as replacements are driven by subjective obsolescence and impacts seem to be increasing with each successive generation, the question is which product lifetime extension instruments are the most effective to actually reduce the environmental impact.

Garry Knight, 2012 (Flickr)

3.6 Laptops

Laptops and other mobile electronic devices such as tablet computers have relatively short lifespans and are resource-intensive. It follows that the production phase usually is the dominant contributor to the overall environmental impact. What is the optimal replacement moment?

LCA studies and the optimal replacement moment

A LCA study by Prakash et al. (2012) shows that extending the lifetime of modern laptops is the recommended strategy from an environmental perspective. Prakash et al. (2012) found that the production phase accounts for 56% of the Global Warming Potential, which is significantly higher than the use phase. Prakash et al. (2012, p. 7) state: "if we assume a realistic energy efficiency improvement of 10% between two notebook generations, the amortization periods are between 33 and 88 years, while if energy efficiency improves by 20% the period is between 17 and 44 years, depending upon the data source used to analyze notebook production. Evidently no notebook has such a useful lifetime." On the basis of a dynamic LCA, Bakker et al. (2014) find that the lifetime of a laptop should be extended from the current average of 4 years, to at least 7 years (and preferably more). There is strong evidence that in the case of laptops, product lifetime extension leads to environmental benefits.

Trends in laptop technology

Kasulaitis et al. (2015) looked at the technological trends that affect the design of laptop computers, in order to understand the impact of these trends on LCA studies. They conclude that (p. 1) "for a variety of attributes, it was found that the material footprint did not change significantly over the period 1999-2008, suggesting that improvements in functionality roughly balanced efficiency gains." In other words, "one cannot assume that dematerialization will automatically lead to material and energy reductions for consumer electronics (p. 1)." This finding is important given the recent development of ultrabooks: a generation of light and very portable laptops. The implicit assumption is that these ultra-light computers will also have a reduced environmental footprint, but Kasulaitis et al. (2015) caution that this may not always be the case.

Conclusion

In the case of laptops, product lifetime extension leads to environmental benefits. The optimal replacement moment was calculated to be (at least) 7 years. In practice, laptops are used for 4 years on average. Even though laptops are becoming more lightweight, this does not necessarily change their environmental impact.

Vivian Chen, 2010 (Flickr)

3.7 Vacuum cleaners

The European Eco-design Directive for vacuum cleaners contains several requirements on energy consumption and durability of the hose and motor life. With regulation in place to stimulate energy-efficiency and longer lasting products, what is the optimal replacement time for vacuum cleaners?

LCA studies and the optimal replacement moment

Perez-Bélis (2017) calculated whether replacing or repairing a vacuum cleaner was preferred, based on a large number of LCA scenarios. The study found that the optimal strategy depends on the energy efficiency of the old model and of the replacement model. Assuming that the old vacuum cleaners are of energy class C, D, E, F, or G and the new vacuum cleaner is of class A (European Union, 2010), replacement is the best strategy. If a vacuum cleaner of class C is replaced by a vacuum cleaner of class A, the new vacuum cleaner should be used for at least 6 years in order to reach the 'environmental break-even point'. In case the old vacuum cleaner was of class G, the break-even point is reached after 3 years. In all other cases (with the exception of a vacuum cleaner with energy label G), it was preferable to repair the vacuum cleaner rather than replace it by one of the same energy class or one class higher. For example, a broken vacuum cleaner with energy label B should be repaired instead of replaced with a label A appliance.

According to Gallego-Schmid et al. (2016), the energy consumption of vacuum cleaners in the EU has increased considerably over the past decades due to the increasing power rating (from 500 W in the 1960s to over 2500 W in 2015), without noticeable improvements in the cleaning performance. At the same time, the market for vacuum cleaners in the EU has been growing by 9% per year. Gallego-Schmid et al. (2016) calculated the prospective impacts of the recently introduced energy measures in the Ecodesign Directive, requiring that vacuum cleaners have a power rating below 900 W after September 2017. The study shows that the implementation of the Ecodesign Directive "will reduce significantly the impacts from vacuum cleaners (37-44%) by 2020 compared with current situation (p. 192)." The authors add: "Moreover, because of expected lower life expectancy of vacuum cleaners (5 years instead of 8 years), reuse and refurbishing should be evaluated to identify opportunities for environmental improvements. (p. 192)."

The assumption in the study by Gallego-Schmid et al. (2016) is that vacuum cleaners last for 8 years. They however note that the European Commission (2013) expects the lifetime might be reduced to 5 years in 2020. Lifespan is an issue, as noted by WRAP (2013). They found that around half of new vacuum cleaner purchasers replace one less than 5 years old, below the expected lifespan, with perceived breakage, poor performance and unreliability as the major reasons for replacement.

The integration of durability criteria in the European Ecodesign Directive aims to change this. The Ecodesign Directive requires that, as of 2017, the motor of vacuum cleaners must have a minimum operational lifetime of 500 hours, and the hose must have a minimum durability of 40,000 oscillations under strain (European Commission, 2014a). Assuming 2 hours of vacuum cleaning per week (roughly 100 hours per year), the vacuum cleaner should last at least 5 years.

Replacement reasons for vacuum cleaners

In spite of the minimum durability criteria in the Ecodesign Directive, there may be other factors that stimulate rapid replacement of vacuum cleaners. A UK-based survey by Salvia et al. (2015, p. 344) found a "generally negative attitude to general maintenance tasks. Half of survey respondents stated that they replace the bag or empty the container of dust when they think it is full, or when the machine does not suck properly (15%), rather than according to manufacturers' instructions (7%) or when indicated by the machine (16%). Similar responses are reported about the frequency of cleaning or changing the filters… Similarly, 16% of respondents do not carry out any of the other fundamental maintenance tasks (e.g. checking that the brush bar is free from hair or dirt)." Salvia et al. (2015) conclude: "brokenness is not necessarily an intrinsic condition of the machine but rather a perceived state in which unwanted effort is required of the user by the item." One of their explanations is that vacuum cleaners have become commodities, new machines are relatively cheap.
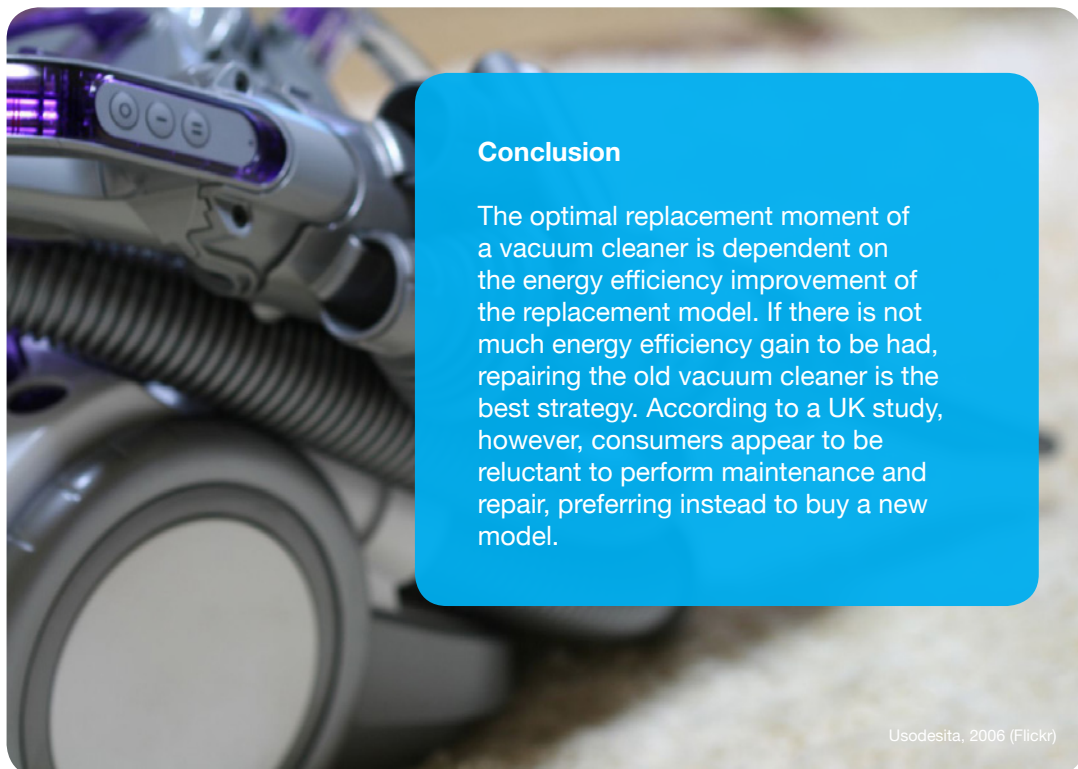
Conclusion

The optimal replacement moment of a vacuum cleaner is dependent on the energy efficiency improvement of the replacement model. If there is not much energy efficiency gain to be had, repairing the old vacuum cleaner is the best strategy. According to a UK study, however, consumers appear to be reluctant to perform maintenance and repair, preferring instead to buy a new model.

Usodesita, 2006 (Flickr)

3.8 Clothing

The textile and clothing industry is one of the world's largest and one of the most polluting industries (Resta and Dotti, 2015). In Western countries, reduced prices and consumers' increased purchasing power contributed to a growing amount of textiles (European Environment Agency, 2014). From 1995 to 2010, textile waste from private households increased from 29,000 tons to 52,000 tons, an 80% increase in 15 years (Laitala and Boks, 2012). According to Laitala and Boks (2012), 28% of binned textiles could have been reused. As garments are used less often, because more clothes are bought, every single garment could easily have a longer lifespan. What is the optimal replacement moment of clothing?

LCA studies and the optimal replacement moment

The authors have not been able to find LCA studies on the optimal replacement moment of clothing and textile products. However, according to WRAP (2012, p. 12), the production of clothing is the most significant lifecycle stage: "It contributes over three-quarters of the carbon footprint, over 90% of the water footprint and around one-third of the waste footprint." The use phase, with clothes washing and tumble drying, is the second most dominant lifecycle stage, representing 26% of the total greenhouse emissions (WRAP, 2012). This leads the UK Department for Environment, Food & Rural Affairs (DEFRA, 2009) to conclude that extending the useful life of clothes (including greater re-use) and changing laundry practices has the potential to create the greatest resource and cost savings.

Muthu (2015, p. 99) tabulated the use phase impacts of different clothing products from several literature references, showing that the accounted primary energy use in the use phase varies from 2% to 93%, in which the lowest percentage was found in a Polyester Blouse with 40 cold washes and no drying; and the highest percentage in a knit cotton golf shirt with 100% heated wash, small load size and 100% electric drying. Muthu concludes (2015, p. 98): "Most of the studies have clearly demonstrated the change in various environmental impacts with different use phase parameters such as washing temperatures, class of washing machines, washing cycles and washing frequencies, drying timings, temperatures, frequencies, drying methods; and ironing timings and temperatures." This implies that LCA calculations may vary per country, as argued by Muthu (2015, p. 93): "The use phase impacts vary depending upon factors such as consumer behaviour, geographical zone in which the product is used and the weather conditions in that zone."

A literature review on fast fashion and quality by Day et al. (2015) states there is evidence that fast fashion has a significant impact throughout the entire product lifecycle, mainly caused by the decreasing lifetime of products. In the UK, 30% of clothes are left unworn at home, which is around 1.7 billion items (WRAP, 2012). A survey among 7950 UK adults (WRAP, 2012) showed there are opportunities for more sustainable purchasing practices. As such, people would like to do more to buy clothes that are made to last, one third of consumers would value a guarantee or indicator for durability by retailers and more environmental information on clothing is desired.

The survey also showed that consumers would buy more pre-owned clothing if greater variety was available and that there is an interest in hiring or leasing clothes if it was made easier, particularly designer dresses and clothes for going out. Laitala and Klepp (2015) have shown that direct reuse saves the most carbon dioxide compared to other end-of-life scenarios, which omits collection, sorting and the redistribution of products and is more comparable to longer use with the first owner.

Situation in developing economies

In most Asian countries old clothing is used by siblings until completely worn out (Muthu, 2015). On 2 March 2016, the BBC wrote that Burundi, Kenya, Rwanda, Tanzania and Uganda might ban imported second-hand clothes and leather sent from Europe and the US. The East Africa Community (EAC) suggested to phase out imports by 2019 and directed member countries to buy their textiles and shoes from within the country to boost local manufacturing and help the economy. "Imported clothes are so cheap that the local textiles factories and self-employed tailors cannot compete, so they either close down or do not do as well as they could." To give an indication of this scale, 81% of all clothing purchases exist of second-hand garments according to Andrew Brooks in his book Clothing Poverty (BBC, 2 March 2016).

Shankar S.,2014 (Flickr)
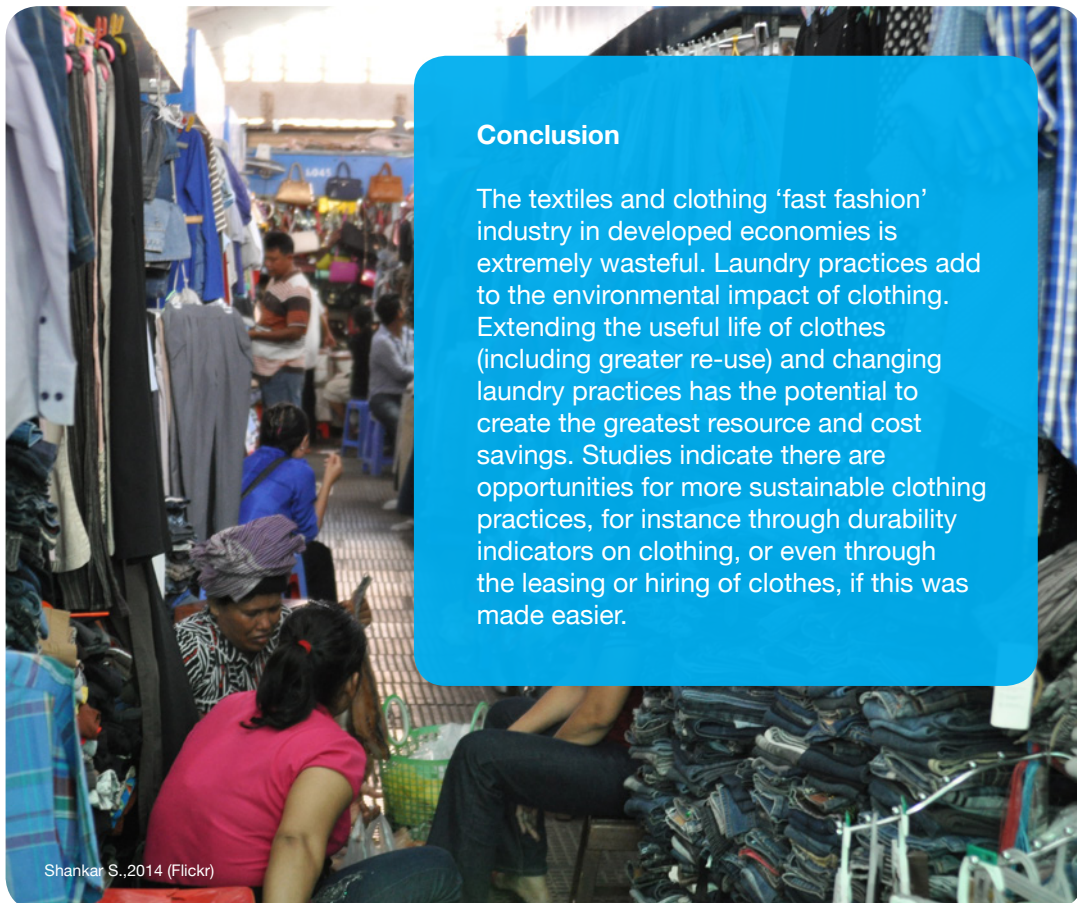
Conclusion

The textiles and clothing 'fast fashion' industry in developed economies is extremely wasteful. Laundry practices add to the environmental impact of clothing. Extending the useful life of clothes (including greater re-use) and changing laundry practices has the potential to create the greatest resource and cost savings. Studies indicate there are opportunities for more sustainable clothing practices, for instance through durability indicators on clothing, or even through the leasing or hiring of clothes, if this was made easier.

3.9 Attention points per product category

This literature review demonstrated the complexity of determining the optimal replacement moment for seven use-intensive products. The number of available studies per product group is limited, and comparing the outcomes is almost impossible, because of variations in chosen system boundaries, product lifespan, use scenarios and data sets (for example regarding material or energy intensity developments over time). It follows therefore that based on the data, there is no one-size-fits-all solution for implementing product lifetime extension instruments. The table below summarizes the main findings, and lists attention points for policy makers per product group.

Main findings from the literature	Recommendations
Washing machines should be at least 10 years old before replacement becomes worthwhile (from an environmental perspective). There is a bias towards European data. Data from developing economies is missing. Consumer use scenarios and use contexts vary greatly across cultures, which impact the optimal replacement moment.	• Develop more Life Cycle Assessment studies that include a range of use patterns in order to arrive at more reliable conclusions. • Promote sustainable use practices to help decrease the environmental impact of clothes washing (for instance cold water washing, or completely filling the machine before washing).
Based on data of developed economies, refrigerators of over 10 years old should be replaced with more energy efficient models. Old refrigerators are however not always taken out of circulation, but often exported to developing economies, where they continue to be used.	• Raise awareness and build capacity on energy-efficient repair in developing economies.
Energy consumption of the latest generations of TVs (UHD, smart) is increasing compared to previous generations of LED TVs. Product replacement could thus undo energy savings which were made in the past. With such rapid technology cycles in the television industry, LCA studies on optimal replacement moments quickly become irrelevant.	• Ensure that the energy consumption of novel generations of TVs does not trend upward again, through appropriate measures in policies, such as the European Ecodesign Directive.
The extraction and manufacturing phases are still the biggest contributors to the environmental impact. The impacts of the use phase are increasing, however, due to the increasing use of network infrastructure.	• Incentivise the extension of the useful life of mobile phones beyond the current 3-4 years, for instance through stimulating refurbishment or modular/repairable designs. • Consider regulating the energy consumption of the network infrastructure, to ensure it keeps functioning energy efficiently.
Product lifetime extension leads to environmental benefits. The optimal replacement moment was calculated to be (at least) 7 years. In practice, laptops are used for 4 years on average. Even though laptops are becoming more lightweight, this does not necessarily change their environmental impact.	• Ensure that the lifetime of laptops is extended, for instance through minimum durability criteria, and stimulating modular/repairable designs.

Vacuum cleaners are often replaced before they are 5 years old. This is less than the expected lifespan. Product lifetime extension is recommendable in most cases. In spite of the minimum durability criteria in the EU Ecodesign Directive, there may be factors that stimulate rapid replacement of vacuum cleaners. One of these factors is a seeming reluctance (in developed economies) to engage in maintenance and repair activities, instead preferring to buy a new (cheap) vacuum cleaner.	• Pay attention to consumer education. • Stimulate better product design (easier to clean and repair).
Extending the useful life of clothes (including greater re-use) and more sustainable laundry practices has the potential to create considerable resource and cost savings.	• Create durability indicators on clothing. • Stimulate new business models (such as leasing or hiring of clothes). • Educate consumers regarding sustainable laundry practices.

Table 3.1 Product-specific measures. The table contains the main findings from literature and attention points for policy makers.

3.10 Discussion

This review of the LCA studies that were performed to determine the optimal replacement moment leads to a number of interesting findings related to product lifetime extension.

1. Successive generations of electronic products are not always more energy efficient. The TV case is a good example, where efficiency improvements are neutralized or even negated by the addition of new features, extra capacity, etc. It follows that older (and thus more energy efficient) generations should be kept 'alive' through upgrades (both in hardware and software), repair and refurbishment. This strategy should be combined with ongoing efficiency improvements of newer models.

2. Replaced products are not always taken out of circulation. If an old product is still functioning, it is often not sent to recycling but sold on the second hand market, given to friends or family, donated or sold to developing economies, etc. This results in product lifetime extension, but also in an addition of the old product to the expanding stock of products. It means that efficiency improvements take much longer to have an effect in the market (Hinchliffe, 2015). All this could be an argument to aim for accelerated phasing out of older generations, and for stimulating energy efficient service and repair in developing economies with a large informal repair sector.

3. Many of the LCA studies reviewed do not do justice to the highly diverse user contexts and cultures. While this is understandable from a scientific perspective (using averages makes the study manageable), it can also lead to results that are overly 'simplistic'. The case study of washing machines showed for instance the widely diverse laundry practices. Also, the fact that the new generation of washing machines with a capacity of 7.5 kg are not used to their full potential (Schmitz et al., 2016) is illustrative of how the 'messy reality' can interfere with more 'theoretical' studies, and potentially distort the results.

For studies on the optimal replacement moment to be useful, they should be modelled as close to the 'real, messy world' as possible. This requires large amounts of data, both technical (i.e. energy efficiency developments) and sociological (i.e. diverse use patterns). Also, the system boundaries should be chosen wisely in order to, for instance, take into account the export of used goods to developing economies. Studies with this magnitude are however rare. To quote Strandbakken (2009, p. 149): "technological and social factors need to be considered simultaneously and holistically, if a goal of increased eco-efficiency of consumption is to be reached." This implies that other tools and methods than LCA studies may be needed to arrive at useful insights regarding product lifetime extension. Such methods should include social and economic dimensions.

Conclusion

The literature review demonstrated the complexity of determining the optimal replacement moment for seven energy-use-intensive consumer products. In the next chapter, different opportunities and barriers for product life extension are discussed, using three distinctly different policy perspectives.

Mitch Altman, 2013 (Flickr)

4. Product lifetime extension opportunities

The report proposes two different approaches towards product lifetime extension, which are named the 'Open Source' perspective, and the 'Closed Loop' perspective. A third policy perspective specifically for developing economies with a large informal repair market is also proposed.

The basic philosophy behind the '**Open Source**' perspective is that the lack of transparency (asymmetrical information between industry and consumers) is one of the causes of shorter product lives. If consumers have better information, they can, in theory, make better buying decisions. Open Source is therefore meant to enable and empower consumers to extend the lifetime of products. It follows that consumers are not only given more power, but also more responsibility. The success of this perspective will depend on consumers taking action, and being enabled and supported by relevant policy measures, non-governmental organisations (NGOs) and industry initiatives.

The basic philosophy behind the '**Closed Loop**' perspective is that product lifetime extension is a strategic business decision. Companies need to (be able to) maintain economic control over their resources and products, in order to close the loop, in line with 'Circular Economy' (EMF, 2013) thinking. The Closed Loop perspective is meant to enable and empower manufacturers to extend the lifetime of products, whilst giving their customers a high-quality product experience. It follows that companies will retain full responsibility over their products, and that alternative business models like 'lease' or 'pay-per-use' are an integral part of the Closed Loop perspective. The success of this perspective will depend on the extent to which these alternative business models are accepted and embraced by both consumers and industry.

These two perspectives (based on literature and expert interviews) are deliberately presented as two extremes, to show the range of options available for product lifetime extension. Both perspectives can co-exist (there is no one-size-fits-all) and all kinds of mixed or 'hybrid' perspectives are possible.

It should be noted that these two perspectives are mostly applicable in developed economies. A policy perspective for developing economies with a large informal repair market is also proposed, based on the expert interviews. This perspective calls for a different set of policy measures, as product life extension is already common practice in many of these economies.

4.1 Open Source perspective

OPEN SOURCE

Enable and support consumers to extend the lifetime of their products

POLICY INSTRUMENTS

Governments

- Law against planned obsolescence
- Minimum durability criteria
- Product lifetime labelling
- Extended product warranty
- Right to Repair legislation

C (Bakker and Schuit, 2016)

Industry

Consumers

- Monitoring of trends in product lifetimes
- Consumer education and information
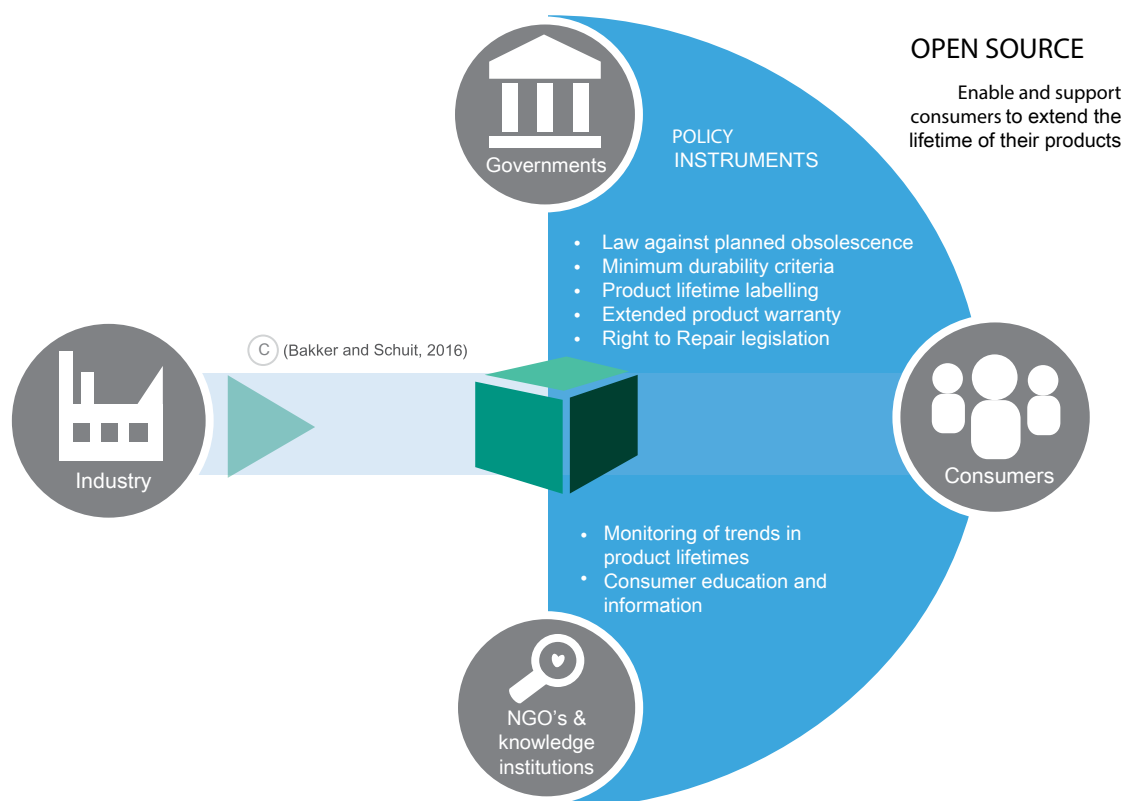
NGO's & knowledge institutions

Figure 4.1 The Open Source perspective can be translated into a number of possible policy measures which will be discussed in the following sections.

4.1.1 Law against planned obsolescence

As the first country in the world, France has made planned obsolescence punishable by law, through Articles L441-2 and L454-6 (March 2016) of the Code de la Consommation. Defined as "all techniques through which any person who places a product on the market plans to deliberately shorten the lifetime of the product, in order to increase its replacement rate", manufacturers can receive two years of imprisonment and be punished with a fine of € 300,000 once planned obsolescence is proven (Ventère, 2016, personal communication, 7 June).[4] According to Baptiste Legay, head of Waste and Circular Economy of the French Ministry for Ecological and Solidary Transition, the new law allows consumers to file class-action lawsuits (Legay, 2016, personal communication, 20 June). This could make the work of 'watchdog' consumer NGOs easier. It could also give whistleblowers a way to be heard.

France has stressed the importance of having an agreed-upon European definition of planned obsolescence at the Environment Council in Luxembourg. According to Erich Ober, Austrian member of the High Level Working Group on Eco-Innovation and the lead of the subgroup 'planned obsolescence', the European Commission is considering to follow France's example, and to make planned obsolescence prohibited by law as well. One of the benefits of such a law is that it can help raise awareness on product lifetimes, for both consumers and producers (Ober, 2016, personal communication, 26 August).

Barriers

As this law was implemented recently and has not yet been tested, it is unclear how this legislation will evolve. NGOs and consumers will have to take action to enforce it. According to Baptiste Legay (2016), France alone cannot extend the lifetime of products as this legislation needs Europe in order to have a considerable market size and to become more meaningful to international manufacturers.

4.1.2 Minimum product durability criteria

Danny Choo, 2011 (Flickr)

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[4] *The official French text of Articles L441-2 and L454-6 (March 2016) reads:*
"Est interdite la pratique de l'obsolescence programmée qui se définit par le recours à des techniques par lesquelles le responsable de la mise sur le marché d'un produit vise à en réduire délibérément la durée de vie pour
en augmenter le taux de remplacement." And: "Le délit prévu à l'article L. 441-2 est punie d'une peine de deux ans
d'emprisonnement et d'une amende de 300 000 euros."

For vacuum cleaners, minimum durability criteria are integrated as mandatory requirements in the European Ecodesign Directive. The motor of vacuum cleaners must have a minimum operational lifetime of 500 hours, the hose must have a minimum durability of 40,000 oscillations under strain (European Commission, 2014b). For lighting, the implementing measure includes requirements for lamp survival factor, lumen maintenance and number of switching cycles before failure (ANEC and Bureau Européen des unions de consommateurs aisbl, 2012). As of 2012, all packaging for light bulbs must provide consumer information about brightness (lumen output) and the bulb's life expectancy (in hours). In the implementing measure for computers, it is specified that the coming revision of the Ecodesign Directive should look into various resource efficiency aspects, such as durability, dismantlability, recyclability, standardised interfaces for rechargers, information requirements on critical raw materials and minimum number of loading cycle and battery replacement issues (Bundgaard et al., 2015).

Barriers

Measurement standards, test standards and verification methods for resource efficiency and durability still need to be developed for a wide range of products. Also, the effectiveness of the current durability criteria for (for instance) vacuum cleaners is subject of discussion in the EU. According to a UK study of Harmer et al. (2015), commissioned by the UK Department for Environment, Food & Rural Affairs (Defra), vacuum cleaners are often disposed of before they are irrevocably broken and replacement products are cheap. This could result in minimum durability criteria being less effective, as vacuum cleaners are generally discarded 'before their time'.

Example: WRAP's buying guides for durable products

WRAP (UK) offers publicly accessible buying guides which manufacturers and retailers can use to produce and procure longer lasting products which can be more easily repaired and have greater environmental benefits. The guides focus on the most beneficial design specifciations that can be 'easy to achieve' within existing product price constraints. The buying guides were developed with retailers, brand manufacturers and the repair industry. (WRAP, 2016)

4.1.3 Product lifetime labelling

The purpose of product lifetime labelling is to influence consumers' purchasing decisions in favor of products with longer lifespans. Different label formats have been examined, for instance showing the minimal lifespan in years or months, showing the useful lifespan in terms of cycles, showing costs per year, or giving a relative score (based on comparing the lifespan among competing products). A study by the European Economic and Social Committee showed that on average, sales of products with a lifespan label increased by 13.8% (p. 2). "We noted a significant influence on purchasing decisions in eight of nine product categories tested: suitcase (+ 23.7%), printer (+ 20.1%), trousers (+ 15.9%), sport shoes (+ 15%), coffee maker (+ 14.4%), washing machine (+ 12.9%), vacuum cleaner (+ 12.3%), and smartphone (+ 11.4%). Only the simulated purchases of televisions were not significantly affected by environmental labelling." The study involved 2917 participants from France, Spain, Czech Republic and Benelux (European Economic and Social Committee, 2016).

Barriers

It can be difficult to reliably measure product lifespan. Most manufacturers know the average lifespan of their products and know how to test their products, but finding consensus on standardised measurement procedures can be challenging. However, this challenge is precisely one of the motivations of a French pilot that is in preparation: a voluntary agreement to experiment with product lifespan labelling.

Another potential drawback of product lifespan labelling is that it refers to an average (minimum) lifespan, which is a statistical number, meaning that not every single product will reach this lifespan. This may not be understood by consumers (who may confuse lifespan information with a guarantee) and occasionally a product might break before its stated lifespan. Furthermore, labelling a product with an expected (minimum) lifespan may have as unwanted side-effect that consumers regard this as the moment they are 'allowed to' replace the product, thus unintentionally normalizing a throw-away culture.

> **Example: Nordic Ecolabel as fore-runner for product lifetime labelling**
>
> As the greatest environmental impact of white goods comes from their use, the Nordic Ecolabel by the Nordic Council of Ministers (Nordic Ecolabelling, 2015) demands that white goods meet environmental requirements without compromising performance. One of the requirements for obtaining a Nordic Ecolabel is that companies have to guarantee that replacement parts shall be available for 10 years from the time that production ceases and that a warranty of at least two years is provided.

4.1.4 Extended product warranty

The EU 1999 Directive on Consumer Sales foresees a minimum legal guarantee period of two years combined with a 6 months period for the reversal of the burden of proof for the defect. This means that only within the first 6 months after purchase it is presumed that the product was faulty from the start. Afterwards, it is the consumer who has to prove that the defect was already inherent in the product when he or she bought it, which is most of the time not possible without an expert investigation (Ober, 2016, personal communication, 23 June). France and Portugal have extended the period for the reversal of proof to two years. A revision of the EU rules on legal guarantee is currently underway. Another opportunity is to prolong the legal guarantee itself for some products. The Danish Consumers Council, for example, repeatedly raised the issue to extend the consumer warranty from two to five years for larger consumer goods such as washing machines (Lauridsen and Jørgensen, 2015).

Barriers

The Danish Trade association states that extended warranty will lead to more expensive products as large inventories of repair materials need to be stocked (Lauridsen and Jørgensen, 2015). Lauridsen and Jørgensen (2015) argue that a five-year warranty not only requires a change in product design, but a change in organization as well, as companies need to develop competences to service products and maintain customer relationships. These competences can be very far from the core business model (Lauridsen and Jørgensen, 2015). Another reason for resistance is that many companies sell extended warranties as a service. A mandatory prolongation of the legal guarantee might undercut their profits (Legay, 2016, personal communication, 20 June), (Ober, 2016, personal communication, 23 June).

FaceMePLS, 2015 (Flickr)
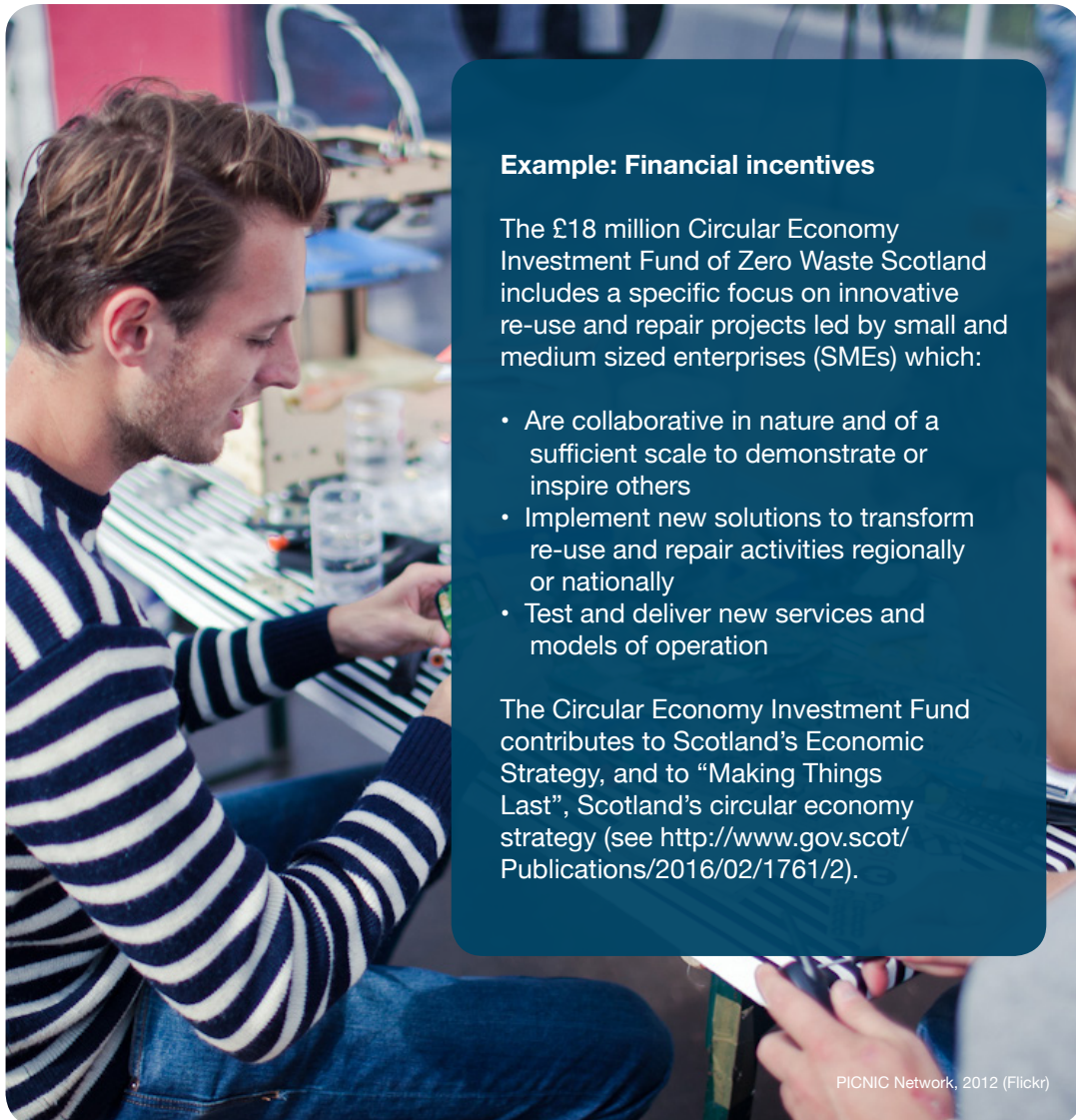
4.1.5 'Right to Repair'

Kyle Wiens, co-founder of iFixit, and others suggest to implement a Right to Repair bill in the USA, that "allows owners and independent repair facilities to have access to the same diagnostic, repair information, and parts made available to the manufacturers, dealers and authorized repair facilities" (Wiens, 2016, personal communication, 29 June). This bill would include publicly accessible service manuals, service parts availability at non-discriminatory pricing to third parties, and access to machine code and firmware updates, among others. If such a bill should pass, it would remove the limitations on repair, allowing extended use of products far beyond the initial warranty at reasonable prices (Wiens, 2016, personal communication, 29 June). Repair by independent repair technicians can be stimulated by reducing Value Added Tax for repair, introducing reuse and repair targets and making it easier to re-categorize disposed products from 'waste' to 'repair ready' (Wiens, 2016, personal communication, 29 June).

The French Consumption Law Decree no 2014-1482 obligates manufacturers and retailers to inform consumers about how long spare parts will be available when consumers buy the product. According to Baptiste Legay of the French Ministry for Ecological and Solidary Transition, this legislation forces manufacturers to think about the question and decide if they want to offer spare parts or not. The decree does not state how consumers must be informed (Legay, 2016, personal communication, 20 June).

Jake Brown, 2008 (Flickr)

Barriers

The Federation of Danish Industries argues that waste received by public waste collection centres must be subjected to 'waste treatment', thereby questioning the legality of swap-sheds, outlets and repair shops. This shows that reuse activities can be considered as a potential threat by the established materials recycling industry (Lauridsen and Jørgensen, 2015). And Salvia et al. (2015) raise the point that consumers sometimes have a negative attitude towards repair. They note the following barriers: 1) consumers are only willing to pay a small fraction of the replacement costs to repair a product, 2) consumers are frustrated and annoyed between the breakdown and completion of the repair service, and 3) aggressive marketing strategies for buying new products reduce the demand for repair services (Salvia et al., 2015).

Example: Financial incentives

The £18 million Circular Economy Investment Fund of Zero Waste Scotland includes a specific focus on innovative re-use and repair projects led by small and medium sized enterprises (SMEs) which:

- Are collaborative in nature and of a sufficient scale to demonstrate or inspire others
- Implement new solutions to transform re-use and repair activities regionally or nationally
- Test and deliver new services and models of operation

The Circular Economy Investment Fund contributes to Scotland's Economic Strategy, and to "Making Things Last", Scotland's circular economy strategy (see http://www.gov.scot/Publications/2016/02/1761/2).

PICNIC Network, 2012 (Flickr)

Example: Danish swap sheds and repair facilities

"Swap sheds and repair facilities are spreading rapidly in Denmark. The most prominent examples are in Næstved, Hjørring and Sønderborg. In Næstved the workers at the public waste collection facility actively engage with the public when they come with reusable items. Before throwing them in the container, the public is asked to reconsider their waste as potentially reusable products and hand them over to the workers, who will take them to the swap shop. The swap shop includes easy repair facilities and a very popular outlet, where recycled products can be bought cheap. The swap shops have a relatively low but rapidly increasing turnover in 2014 (approximately 30.000 €/year), and new swap shops are now opening up at many waste management facilities following the examples of Næstved, Hjørring and Sønderborg" (Lauridsen and Jorgensen, 2015, p. 191).

Example: Nudie Jeans' free repair service

The Swedish denim label Nudie Jeans offers free repairs on all Nudie Jeans since 2010. Currently there are 19 repair stores worldwide. If customers do not live near one of these, the company sends out a free Repair Kit, to enable self-repair. In 2015, no less than 21,331 worn jeans were repaired. The idea behind Nudie Jeans Repair Shops is that the jeans can be repaired, resold as second-hand or donated to a recycling program. In a Guardian interview, the CEO of Nudie Jeans, Palle Stenberg, said: "It's not about how much we spend to make one unit. It's about how long you can make a single pair of jeans last" (Borromea, 2014).

Example: Fairphone's challenge of setting up a spare parts supply chain

The Dutch company Fairphone aims to make mobile phones that last at least 5 years. Through a modular design and by offering spare parts at an affordable price to stimulate self-repair, Fairphone attempts to break the cycle of constant replacement of broken or out-of-date phones. As a relatively small company with a limited cash flow, Fairphone had to set up their own spare parts supply chain, which was a significant challenge. According to Gaye (2016): "Figuring out stock requirements and financing was only part of the equation. We also had to educate our manufacturer as to why we wanted to do this, convince them to supply us with small volumes of parts, improve quality control and tackle issues like packaging and shipping something as small as, say, a camera. … In fact, we realized that what we were trying to do was considered pretty radical by others in the electronics sector."

4.2 Closed Loop perspective

CLOSED LOOP

Enable manufactures to retain
full responsibility over
their products in order to extend
product lifetime

POLICY
INSTRUMENTS

Individual Producer Responsibility •
Removeal of legal barriers for •
refurbishment and remanufacturing
Alternative business models •
User privacy laws •

•

Governments

Industry

C (Bakker and Schuit, 2016)

Consumers

•
Monitoring of trends in product lifetimes •
Monitoring of consumer privacy issues
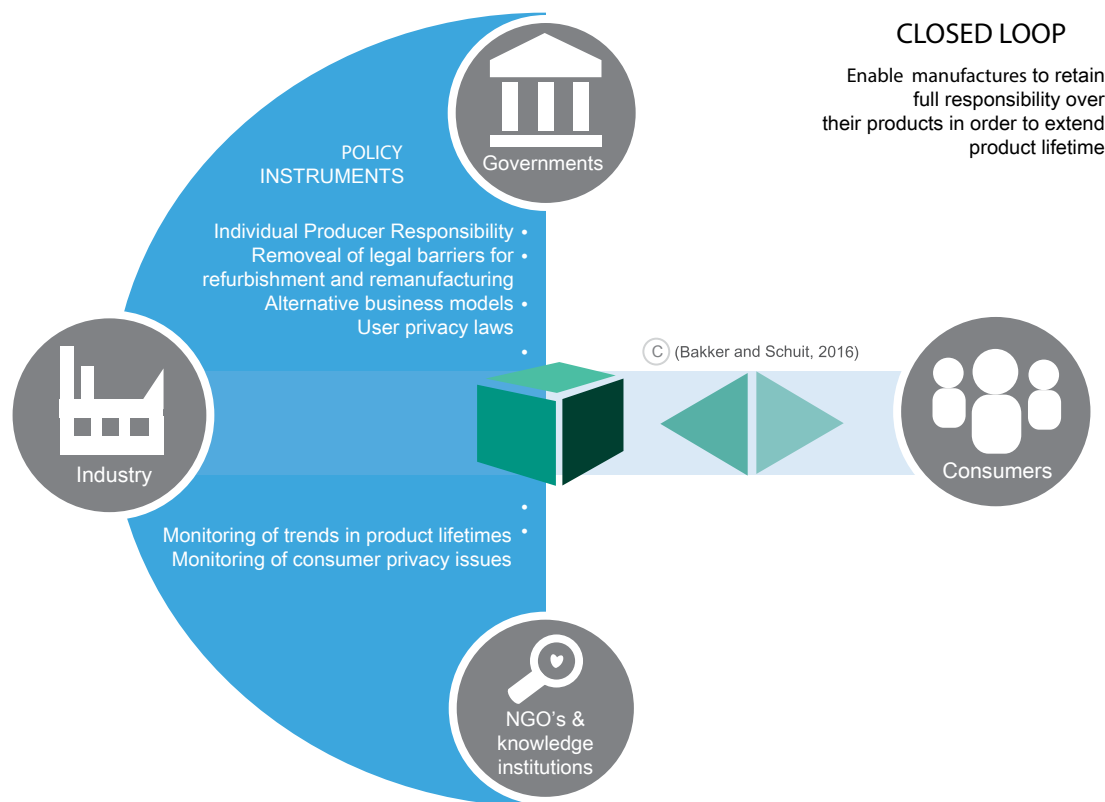
NGO's &
knowledge
institutions

Figure 4.2 The Closed Loop perspective can be translated into a number of possible policy measures which will be discussed in the following sections.

4.2.1 Individual Producer Responsibility

EPR, or Extended Producer Responsibility, is an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle (European Commission, 2014). In Europe, the EPR is enacted through collective compliance schemes. For some products, individual schemes (IPR) could be considered. An IPR makes producers individually responsible, financially and/or physically, for their products at the end of life. It thereby intends to create an economic and/or commercial incentive for producers to make products easier repairable, to upgrade, reuse or recycle (IPR Working Group, 2012).

The INSEAD Working Group on IPR adds: "An examination of IPR systems revealed that the Japanese e-waste recycling system has led to a series of tangible improvements in the design of products to improve their recyclability' (INSEAD IPR Network, 2010). Based on experiences in Japan, INSEAD concludes that brand-based approaches can work and IPR is a fundamental and achievable requirement that needs more development and implementation.

Barriers

One of the barriers is that identification and/or sorting of products in waste streams can be a challenge when recovery costs have to be allocated to individual producers. However, a study by O'Connel et al (2013) concludes that as RFID (Radio-Frequency Identification) can achieve much greater brand or model identification than has been considered feasible up to now, this technology can play a role in allocating recovery costs to individual producers. According to the INSEAD Working group on IPR, concerns of policy makers that Individual Producer Responsibility (IPR) would lead to an increased level of orphan waste (products with unknown manufacturer) is misplaced. In Japan, only 5% of the recycled products constituted orphaned products, whereas the European EPR systems had a 'free riders' level of 10-20% in 2010 (INSEAD IPR Network, 2010).

Example: Individual Producer Responsibility (IPR) in Japan

In Japan, the Specified Home Appliances Recycling Law (SHARL) was enacted in 1998 and came into force in April 2001. Under the law, producers of air conditioners, televisions, fridges/freezers and washing machines are required to take back their discarded products, dismantle them and meet reuse, recycling and recover targets between 50%-60%. Under the law, retailers are mandated to accept end-of-life products from consumers when they sell products similar to the replacement product as well as products they sold themselves in the past. They are required to deliver collected products to regional facilities set up by producers and are permitted to charge consumers a collection fee to cover these costs. Producers have the operational responsibility for the treatment and recycling. (INSEAD IPR Network, 2010)

4.2.2 Removal of legal barriers for refurbishment and remanufacturing

Globally, a large number of industries are practicing remanufacturing. As reported by the Centre for Remanufacturing and Reuse (CRR), at Volkswagen each year 15,000 engines are reconditioned, reusing 70% of the material at half the cost as compared to new. Hence, remanufacturing not only contributes positively to the environment by conserving resources, it is also an economically viable solution (CRR, 2011). There remains a huge untapped potential for remanufacturing.

Barriers

According to a Brazilian (Bouzon and Govindan, 2015), two Chinese (Subramanian et al., 2014, Lau and Wang, 2009) and a Malaysian study (Shaharudin et al., 2015) in which manufacturers were interviewed on the perceived barriers for reverse logistics, a lack of legislative pressure is often perceived as the biggest barrier, followed by lack of initial capital to invest in reverse logistics.

Other barriers that are mentioned are low commitment and lack of reverse manufacturing experts at business management level (Abdulrahman, 2014); uncertainty about product returns in terms of quality, quantity and timing (Shaharudin et al., 2015), causing an unpredictable flow (Starostka-patyk et al., 2013), customer perception of recovered products being of lower quality thereby commanding lower prices than new products in the market (Shaharudin et al., 2015) and unclear potential financial benefits of reverse logistics (Starostka-Patyk, 2013). Although reverse logistics is gaining importance, poor logistic infrastructures form a great challenge, for instance in Brazil (Bouzon et al., 2015). A survey, in which 105 Indian organizations in the automobile, paper, food and beverage, and electronics sectors were asked to describe barriers to recovery, confirms these results (Ravi and Shankar, 2015).

According to Sharma et al. (2016, p. 1888), "several countries, including Brazil, China and Japan have prohibited or limited imports of used/refurbished/remanufactured medical equipment. Even when imports are allowed, hospitals are reluctant to buy them, raising deep concerns about the quality and usability." This illustrates the profound trade barriers that still exist. On the one hand, governments wish to protect their internal markets, allowing domestic remanufacturing, but prohibiting the import of used products or parts. On the other hand, it also demonstrates the deep lack of confidence in the quality of refurbished or remanufactured products. Better quality standards and warranties for refurbished and remanufactured products might help. Sharma et al. (2016, p. 1888): "Many of these barriers likely occur because lack of common and globally accepted definition of remanufacturing and standards that distinguishes remanufactured products from used products." The recently concluded H2020 project 'European Remanufacturing Network" has published an overview of barriers to remanufacturing at https://www.remanufacturing.eu/wp-content/uploads/2016/09/ERN-Key-Barriers-for-Remanufacturing.pdf.

Example: International Resource Panel

The International Resource Panel (http://www.resourcepanel.org) is currently developing a report on current and potential resource efficiency contributions of remanufacturing, refurbishment, repair and direct reuse. It aims to shed light on existing barriers for increasing market expansion of product lifetime extension practices and quantify the potential gains through barrier removal.

4.2.3 Alternative business models

This involves the shift from 'owning' a product, to 'using' it (through for instance leasing or pay-per-use), in other words, the shift from the classic ownership model to alternative business models. The manufacturer retains control over the used products, which may facilitate their recovery, as well as the recovery of resources. Consequently, these concepts seem particularly interesting from a circular economy perspective as they have the potential of decoupling economic growth from material input (Poppelaars, 2016).

Barriers

The shift from 'owning' to 'using' has been receiving a lot of attention with the success of Uber, Airbnb and many other ICT-enabled businesses. It has inspired a whole new terminology: the sharing economy, collaborative consumption, etc. There is crticism as well. Uber for instance has been criticized for its 'cavalier attitude' towards liability. "If you summon a driver, you're putting your life in their hands. Is that driver insured properly? Does he have liability insurance?" (Hobica, 2016), as well as criticism around the rights of and protections of the drivers in their more unclear employment and ownership situations. The majority of the 'access' and 'performance' business models take place in Business-to-Business markets, where long-term service contracts and lease contracts are much more common. There is not yet widespread acceptance of these alternative transaction models in the Business-to-Consumer market.

With the onset of new transaction models and product-service systems, companies will increasingly gain access to personal data. Thus, privacy will need to be protected to prevent companies from accessing and (mis)using sensitive personal information.

Example: Access models

In the 'access' model users pay for access instead of ownership. Several business model examples have already arisen in the private sector such as GreenWheels that stimulates shared car use, Mud Jeans that allows customers to lease Jeans and Vigga Baby Clothes where parents can lease organic baby clothing. M-Kopa uses a pay-as-you-go model to make solar panels accessible to rural Kenyans in the informal economy who have irregular incomes and are not connected to the power grid. In the performance model, revenue streams come from payments for the performance that is delivered. A well-known example is taking clothing to a dry-cleaner.

Susan Sermoneta, 2006 (Flickr)

4.3 Policy measures for developing economies

Experts from developing economies indicate that there is a considerable difference between developing and developed economies concerning product lifetime extension. Although enforced legislation is absent, product lifetime extension often occurs naturally in developing economies. This can partly be explained by lower incomes (Nukusheva, 2016, personal communication, 8 August), (Hanafi, 2016, personal communication, 26 August). Instead of a 'throw-away' culture, a repair culture exists in which consumers try to get the most out of their products by getting them fixed (Nukusheva, 2016, personal communication, 8 August) or giving them to relatives or staff with lower incomes (Hanafi, 2016, personal communication, 26 August).

Many developing economies have large, informal secondary markets, facilitated by online sales platforms (equivalents of Ebay) (Hanafi, 2016, personal communication, 26 August) or traditional markets such as the Nigeria Alaba International Market (Nukusheva, 2016, personal communication, 8 August). The informal market, where repair is cheaper than in authorized service centres (Hanafi, 2016, personal communication, 26 August), is condoned by the government as it creates employment (Nukusheva, 2016, personal communication, 8 August).
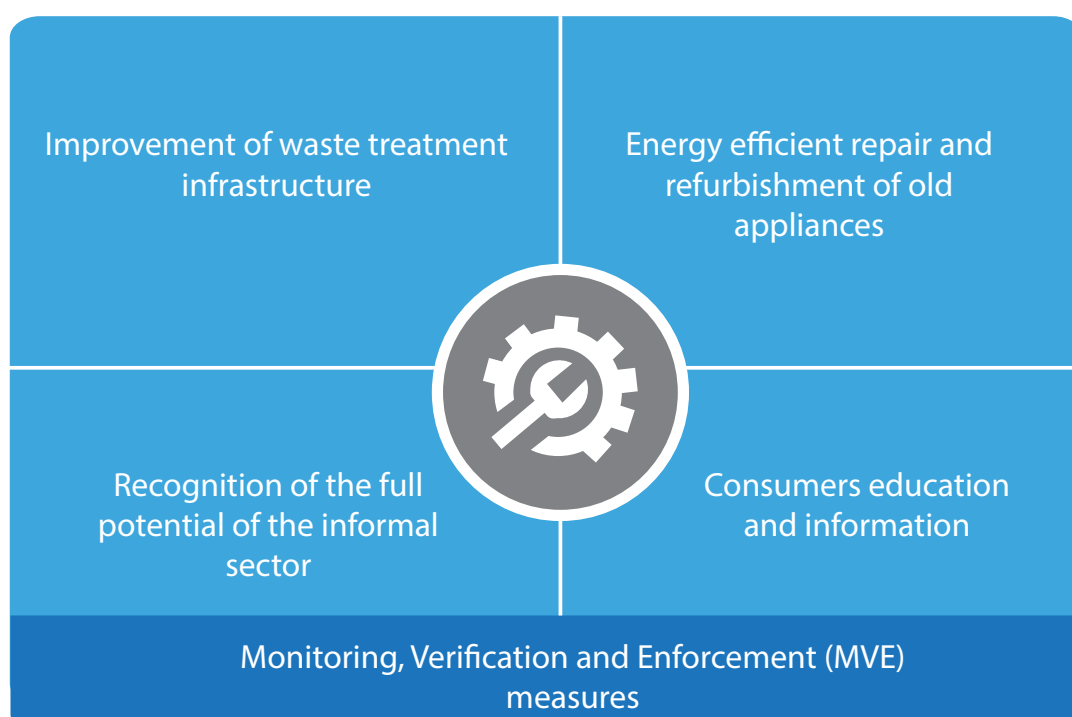

Figure 4.3Possible policy measures for product lifetime extension in developing economies, further discussed below.

Institute for Money, Technology and Financial Inclusion, 2010 (Flickr)

4.3.1   Creating a better waste treatment infrastructure

The disposal of products and parts that cannot be repaired is an issue. Although informal waste pickers re-utilize materials for financial gain, materials that are considered as 'waste' are burned or disposed of in the sewage system. This also poses dangers to workers' and communities' health. A formal, environmentally sound and safe waste management system is needed for such materials. In order to make such a system function properly, public education on how and where to dispose products and substances is required.

Although it is known that the informal market is well-developed, exact data on its size and practices is lacking. From an environmental perspective, more data is needed on how parts and components that cannot be repaired reach their end-of-life. Based on this data, alignment between a formal waste management system and the informal market can be created.

4.3.2   Stimulating energy efficient repair and refurbishment of old appliances

In many low-income developing economies, high-value products such as consumer electronics and household appliances are reused and repaired for many years. From an environmental perspective, the real challenge is not how to prolong product lifetime, but how to improve the energy efficiency of these appliances. According to Van Burskirk et al. (2007), the lack of an institutional infrastructure to implement energy efficiency regulations is a key problem. One of the suggestions is to promote and increase appliance efficiency in the used and rehabilitated appliance market, for instance through training and the provision of energy efficiency repair manuals (Van Buskirk et al., 2007).

4.3.3 Recognizing the full potential of the informal repair market

In many developing economies entirely new informal economic sectors have evolved over the past decade, which revolve around trading, repairing and regaining materials from redundant electronic devices and appliances (Streicher-Porte et al., 2005). Although in some economies repair activities represent a source of income for many people, these professions are often not recognized, despite their usefulness for society. This sometimes results in poorly controlled recycling of hazardous materials with risky techniques. Most of the participants in this sector are not aware of the risks, do not know of better practices or simply have no access to investment capital to finance profitable improvements (Streicher-Porte et al., 2005). It becomes urgent to recognize these professions and offer them social rights, official status, and training. This can be done through a range of measures, for instance by simplifying bureaucratic procedures involved in registration of an informal enterprise, and offering benefits and incentives in return for paying taxes; by offering social protection and legal rights (i.e. universal pensions and health coverage, property rights, labour rights and business rights) and by offering support such as financial services, enterprise support and infrastructure services (Chen, 2012).

4.3.4 Educating consumers through energy and other eco-labels, and other tools

As the middle class is growing and their spending power increases, households can invest in high-quality, longer lasting and/or energy efficient products. Energy efficiency labeling, as well as eco-labels that focus on the environmental impacts of products (for instance carbon footprints or multi-issue labels), and wider information or awareness-raising campaigns, can help consumers to take informed decisions.

4.3.5 Monitoring, verification and enforcement (MVE) measures

Monitoring, verification and enforcement activities are often missing in developing economies (Nukusheva, 2016, personal communication, 8 August). MVE measures need to be established in order to ensure the effectiveness and implementation of the above-mentioned instruments.

Allison Meier, 2011 (Flickr)

5. Conclusion

The objective of this study was to provide recommendations on the opportunities available to consumers, private sector and governments of developed and developing economies to address product lifetime extension. Product lifetime extension is about more than 'just' creating durable products that are used for a long time. Lifetime extension strategies such as maintenance, upgrading, repair, refurbishment and remanufacturing were also considered in this study. Based on the initial research questions, the main findings can be summarized as follows:

1. To what extent have product lifetimes been decreasing, in industrialized societies?

There is some empirical evidence that the lifetime of a range of consumer products has been decreasing over the past decades (in developed economies), but more research needs to be done to support the evidence base. The authors have not been able to find consistently monitored product lifetime data from developing economies.

2. Why is product lifetime extension not happening yet?

The reasons for rapid replacement rates are varied and complex. Industry should not be pointed to as the only culprits – consumers play a role too, and should be supported by governments and the third sector. However, the widespread dissatisfaction with the lifetime of products has not translated into meaningful action. Solutions are needed that engage and address all the relevant actors in society.

It should be noted that this conclusion is mainly relevant for developed economies, where rapid replacement cycles have become a normal part of everyday life. In general, the developing economies with a higher gross national income show similar patterns of consumption as the developed economies (Echegeray, 2015). In lower income economies, the situation is different, as large informal repair markets are common and there seems to be a culture of keeping products in use for longer.

3. When does product lifetime extension make sense from an environmental perspective? In other words, what are the optimal replacement moments for a number of selected products?

The report reviewed products with a dominant environmental impact in the use phase. Timely replacement by more efficient products could result in higher energy and/or water savings than product lifetime extension. The literature review demonstrated the complexity of determining the optimal replacement moment for seven use-intensive products: washing machines, refrigerators, TVs, mobile phones, laptops, clothing and vacuum cleaners. The number of available studies per product group was limited, and comparing the outcomes was difficult because of variations in chosen system boundaries, assumptions about product lifespan, use scenarios and varying data sets (for example regarding material or energy intensity developments over time).

The literature indicates that washing machines and refrigerators should be used for at least 10 years before they can be replaced with a more energy-efficient model. Vacuum cleaners, clothing, mobile phones and laptops are usually replaced 'before their time' and should be (re)used for longer, although pinpointing an exact replacement moment is very difficult. In the case of TVs, it makes sense to keep older LED models in use instead of replacing them with newer, less energy efficient 4K models. It follows that each product category requires a specific approach and set of policy measures.

4. What product-specific policy measures and opportunities for product lifetime extension follow from the conclusions of Question 3?

The product review shows that successive generations of electronic products are not always more energy efficient; replaced products are not always taken out of circulation; and the reviewed LCA studies do not do justice to the highly diverse user contexts and cultures. This makes it important to always consider both energy efficiency and product lifetime extension in conjunction, and to develop more elaborate LCA scenarios, which will require large amounts of data; both technical (i.e. energy efficiency developments) and sociological (i.e. diverse use patterns). Also, the system boundaries should be chosen wisely in order to, for instance, take into account the export of used goods to developing economies.

It follows that it is difficult to derive product-specific policy measures from this literature review. Monitoring product lifespans and collecting data on real-life use patterns for products in both developed and developing economies is a first (and important) step. Reliable data is currently missing and this hampers the development of evidence-based policy measures.

5. What general opportunities and measures for product lifetime extension, for governments, manufacturers and consumers from both developed and developing economies, follow from the answers to Questions 1-4, the scientific literature and the expert interviews?

Three perspectives with related policy measures are presented in the report. Two of these are mostly applicable to developed economies: the "Open Source" and the "Closed Loop" perspective. The third perspective looks specifically at developing economies with a large informal second-hand and repair market.

The Open Source and the Closed Loop perspective differ in their assignment of the responsibility for product lifetime extension. The Open Source perspective focuses on the empowerment of consumers to extend the lives of the products they own. The Closed Loop perspective puts the responsibility with manufacturers, to create and capture value from their products over multiple life cycles. It follows that alternative transaction models like 'lease' or 'pay-per-use' are part of the Closed Loop perspective. The perspectives highlight different positions and present different sets of policy approaches regarding product lifetime extension.

ju5ti, 2012 (Flickr)

6. Recommendations

Recommendations for developed economies

For developed economies, the report describes two policy perspectives related to product lifetime extension. The Open Source perspective is based on the idea that if consumers have better information, they can make better buying decisions. The success of the Open Source policy perspective will depend on consumers taking action, supported by relevant policy measures, NGOs and industry initiatives. The report recommends the following short/medium-term policy measures:

• Consider adoption of a law against planned obsolescence: Planned obsolescence was recently made punishable by law in France (through articles L441-2 and L454-6 of the Code de la Consommation). It is recommended to evaluate the implementation of the French law and, if effective, to consider EU-wide adoption and adoption in other countries/regions.

• Introduce minimum durability criteria through ecodesign or other directives: The European Ecodesign Directive already has minimum durability criteria for light bulbs and vacuum cleaners, and more measures are planned. The criteria in the European Ecodesign Directive could be extended and measurement standards, test standards and verification methods for durability and resource efficiency could be developed for a range of products.

• Consider the introduction of product lifetime labelling: A comprehensive study by the European Economic and Social Committee (2016) indicates that consumers respond positively to product lifetime labelling. More research and testing needs to be done to study the effectiveness of lifetime labels, and to develop standardized measurement procedures. If product lifetime standards are based on manufacturers' data, they have to be willing to participate, thus incentives need to be introduced.

• Extend product warranty: France and Portugal have extended the period for the reversal of the burden of proof from 6 months to two years. It is recommended to evaluate the French and Portuguese measures and, if successful, to consider making this an EU-wide measure and introducing it in other countries/regions.

• Introduce Right to Repair legislation: Repair needs to be affordable and accessible for consumers, for instance through publicly available repair manuals. A reduction of Value Added Tax on repair can further incentivize actions in this area. In France, manufacturers and retailers are obliged to inform consumers on spare part availability. It is recommended to evaluate the 2016 law (decree nr. 2014-1482) and, if effective, to consider adoption at EU level and introduction of similar legislation in other countries/regions.

• Monitor trends in product lifetimes: Monitoring the trends in product lifetimes of a range of energy use-intensive products consistently, over a number of years, can track the impact from different generations of products and provide up-to-date suggestions for lifetime extension.

• Educate and inform consumers: The promotion of the development of (for instance) product buying/use guides, or consumer awareness/marketplace campaigns, can increase the understanding of product durability, induce a positive consumer attitude towards product maintenance and repair, and encourage consumers to hold companies to account.

The second policy perspective is called Closed Loop. It is based on the idea that product lifetime extension is a strategic business decision. To 'close the loop' is for companies to (be able to) maintain economic control over their resources and products over the product's entire lifetime, including the consumer use stage, through alternative business models (like lease or pay-per-use). This incentivizes the development of durable and reusable products. The success of this perspective will depend on the extent to which these alternative business models are accepted and embraced by both consumers and industry. The report recommends the following short/medium-term policy measures:

• Consider the introduction of individual producer responsibility (IPR) for selected product categories: It is recommended to evaluate the Japanese IPR regulation for air conditioners, TVs, refrigerators and washing machines, and to explore if a translation to other countries' contexts is feasible.

• Remove legal barriers for refurbishment and remanufacture: The development of international standards for remanufacturing and the introduction of warranties and a tax reduction on remanufactured products can provide incentives. There is also a need to address trade barriers that prohibit the import of product parts that are to be remanufactured.

• Stimulate the acceptance of alternative business models (the shift from 'owning' to 'using' products) in the Business-to-Consumer market: This includes addressing privacy and other liability issues pro-actively.

Recommendations for developing economies

For developing economies in which the informal second-hand and repair market is highly developed, the report recommends the following policy measures:

• Improve waste treatment infrastructure: In many economies a formal, environmentally sound and safe waste management system is needed. In order to make such a system function properly, public education on how and where to dispose products is required.

• Ensure recognition of the full potential of the informal sector: Informal economic sectors that revolve around trading, repairing and regaining materials from redundant products currently lack access to investment capital and information to make repairs energy efficient, safe and environmentally sound. It is recommended to recognize these professions and offer them social rights, official status, and training.

• Educate and inform consumers: The introduction of energy efficiency labelling, other eco-labels and awareness campaigns can stimulate the more affluent households to invest in high-quality, longer lasting and/or energy efficient products.

• Develop monitoring, verification and enforcement (MVE) measures to ensure that energy efficiency and product lifetime standards are met.

Recommendations for the 10YFP Consumer Information Programme for Sustainable Consumption and Production (CI-SCP)

The 10YFP Consumer Information Programme for Sustainable Consumption and Production (CI-SCP) could contribute to promoting a longer lifetime for products through the following measures:

• The CI-SCP can work with consumer organizations to develop buying guides for durability and repair of products, for different economies. Such guides could be modelled on the examples of WRAP: see http://www.wrap.org.uk/content/buying-guides-durability-and-repair. Buying guides could stimulate the acquisition of durable and easy to maintain products.

• The CI-SCP could work with existing platforms to include lifetime extension criteria in product testing and reviews.

• The CI-SCP could assist with the development of product use guides, to give advice on how to best use products for optimal energy efficiency and a long lifetime. In the case of televisions, for instance, display modes, screen brightness and the level of room lighting can significantly affect energy use, but consumers often do not know which settings are the most energy efficient. In line with this, efforts could look into making such settings the default option.

• In conjunction with this, the CI-SCP could create awareness raising campaigns about buying for life. The idea of 'total cost of ownership', for instance, is not yet well understood. For consumers, it can be more cost-efficient to invest upfront in a high-quality product than to have to replace a low-quality product after a short period.

• The CI-SCP could stimulate the shift to service models (from owning to using a product through for instance leasing or pay-per-use business models) by collecting and promoting innovative business practices. Interactive formats could be used such as videos or social media. To do so, the CI-SCP could put an emphasis on sharing such practices between economies, and to feature leading cases from developing economies.

• The CI-SCP could collaborate with knowledge institutes and universities to collect data on the real-life use of products in both developed and developing economies, for instance with the Life Cycle Initiative, or relevant industry associations.

• To raise awareness on the issue, the CI-SCP could integrate consumer information components focusing on product lifetimes in existing e-learning courses. For instance, massive open online courses (MOOCs) on Sustainable Consumption and Production, or on the Circular Economy. The case studies on innovative business practices could be useful input for this.

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