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Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence"

Final report

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Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence"

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by

Siddharth Prakash, Günther Dehoust, Martin Gsell, Tobias Schleicher
Oeko-Institut e.V. – Institute for Applied Ecology, Freiburg

Prof. Dr. Rainer Stamminger
University Bonn, Institute for Agricultural Engineering, Bonn

On behalf of the German Environment Agency

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Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

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Oeko-Institut e.V. – Institute for Applied Ecology Research Division 'Sustainable Products & Material Flows'
Merzhauser Str. 173
79100 Freiburg
Germany

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Dr. Ines Oehme, Fiona Knieling

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Abstract

The overall aim of the project is to create a sound data base for describing and assessing the phenomenon of obsolescence, and trends on lifespan and use times, and based on this, to develop strategies against obsolescence. The results show that there are various reasons for replacing electrical and electronic appliances. Material, functional, psychological, and economic obsolescence operate in conjunction in highly complex ways. Even the causes of material obsolescence are quite diverse and pinpointing any one specific cause is difficult. However, the study confirms that the first useful service life of most of the analysed product groups has decreased over recent years. At the same time, increasing numbers of electrical and electronic appliances are being replaced although they are still in working order. In such cases, the desire to possess an even better appliance is key. It was also found that an increasing proportion of appliances are replaced or disposed of before they reach a first useful service life of 5 years. From an environmental perspective, long-life products perform better in all environmental impact categories than short-life products. The economic performance of long-life products depends largely on the difference between the prices of long-life and short-life products, as well as on costs for repair and upgrades required to achieve a longer use time. Against the background of technological development and innovations in electrical and electronic appliances, *requirements pertaining to product lifespans* and *standardization* build the core of strategies against obsolescence. Further requirements include innovative service models of manufacturers, minimum requirements for software, improved consumer information, extended obligations to inform by manufacturers, and improved reparability of the products.

Kurzbeschreibung

Das übergeordnete Ziel des Vorhabens ist, eine fundierte Datengrundlage zur Beschreibung und Beurteilung der Erscheinung Obsoleszenz bzw. der Trends der erreichten Produktlebens- und Nutzungsdauer zu schaffen und darauf aufbauend handlungssichere Strategien gegen Obsoleszenz zu entwickeln. Die Ergebnisse zeigen, dass die Elektro- und Elektronikgerate aus vielfaltigen Gründen ersetzt werden. Dabei wirken werkstoffliche, funktionale, psychologische und ökonomische Obsoleszenzformen zusammen und erzeugen ein hochkomplexes Muster. Selbst die Ursachen der werkstofflichen Obsoleszenz sind in der Regel sehr divers und ermöglichen somit keine eindeutige Schwerpunktsetzung. Die Analyse bestätigt außerdem, dass die Erst-Nutzungsdauer von den meisten untersuchten Produktgruppen in den letzten Jahren abgenommen hat. Dabei wurde festgestellt, dass mehr Elektro- und Elektronikgerate ersetzt werden, obwohl sie noch gut funktionieren und der Wunsch nach einem besseren Gerat kaufentscheidend ist. Auf der anderen Seite wird auch festgestellt, dass ein beträchtlicher Anteil von Elektro- und Elektronikgerate ersetzt und entsorgt wurde, bevor die Gerate die durchschnittliche Erst-Nutzungsdauer oder das Alter von 5 Jahren erreicht haben. Aus ökologischen Gesichtspunkten schneiden die langlebigen Waschmaschinen, TV-Gerate und Notebooks in allen Umweltkategorien besser ab als die kurzlebigen Varianten. Ob die Anschaffung eines langlebigen Gerätes auch ökonomisch sinnvoll ist, hangt entscheidend davon ab, wie hoch der Unterschied der Anschaffungskosten zwischen kurz- und langlebigen Produkten ist und ob kostenaufwändige Reparaturen/Aufrüstungen durchgeführt werden müssen, um eine längere Nutzungsdauer zu erreichen. In Anbetracht der technologischen Weiterentwicklungen und Innovationen bei Elektro- und Elektronikgeraten bilden *Lebensdaueranforderungen, Standardisierung und Normung* den Kern der übergeordneten Strategien gegen Obsoleszenz. Darüber hinaus müssen innovative Service-Modelle der Hersteller, Mindestanforderungen an die Software, Verbesserung der Verbraucherinformationen, Erhöhung der Informationspflichten der Hersteller und verbesserte Reparaturfähigkeit der Gerate ebenfalls umgesetzt werden.

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°dH	Degrees of water hardness
AGP	Accelerated Graphics Port
ALOP	Agricultural Land Occupation
ATSC	Advanced Television Systems Committee (US Standards organization for digital television)
BGA	Ball Grid Array
CAMA	Canadian Appliance Manufacturer Association
CCFL	Cold Cathode Fluorescent Lamp
CPU	Central Processing Unit
CO_2	Carbon dioxide
CRT	Cathode Ray Tube
DUT	Device Under Test
DVB-T	Digital Video Broadcasting – Terrestrial
EEE	Electric and Electronic Equipment
EEPROM	Electrically Erasable Programmable Read-Only Memory
e-caps	Electrolytic capacitors
EMC	Electromagnetic compatibility
eq.	Equivalent
ESR	Electrical series resistance
FEP	Freshwater eutrophication potential
GfK	*Gesellschaft für Konsumforschung*
GWP	Global warming potential
HbbTV	Hybrid Broadcast Broadband TV
HDD	Hard Disc Drive
HH	Household/s
Hz	Hertz
ICT	Information and communications technology
IOA	Input-output analysis
ISDB-T	Integrated Service Digital Broadcasting – Terrestrial
CED	Cumulative energy demand
kHz	Kilohertz
kWh	Kilowatt-hour
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCD	Liquid Cristal Display
LED	Light Emitting Diode
MJ	Megajoule
NGO	Non-Governmental Organisation
N	Nitrogen
nm	Nanometre
NMVOC	Non-Methane Volatile Organic Compounds
OEE	Office of Energy Efficiency (Canada)
P	Phosphorus
PC	Personal computer
PC/ABS	Polycarbonate/acrylonitrile butadiene styrene

PCI	Peripheral Component Interconnect (bus standard)
POFP	Photochemical Oxidant Formation Potential
SSD	Solid State Drive
SHEU	Survey of Household Energy Use
SMD	Surface Mounted Device
SMT	Surface Mounted Technology
SO_2	Sulphur dioxide
StiWa	*Stiftung Warentest* (German Consumer Association)
t	Tonne
TAP	Terrestrial Acidification Potential
USB	Universal Serial Bus
USDOE	US Department of Energy
V	Volt
Vcc	Voltage at the common collector
WDP	Water Depletion Potential
WEEE	Waste electrical and electronic equipment
WIA	Windows Image Acquisition (image processing interface)

Summary

Background

Products of high-tech service economy of the 21st century cause significant environmental impacts, basically due to two main reasons: Firstly, the number of products has been growing steadily and secondly, to some extent relatively short product usage times can be observed.

The resulting volume of waste from electrical and electronic equipment as well as an ever shorter technical life or useful life-time of products are perceived in the public arena to be directly related to the phenomenon commonly referred to as *'obsolescence'*. While in the earlier discussions on obsolescence in the 1960s and 1980s, the available amount of resources was almost considered to be unlimited and the different number of substances used in products were considered to be low, aspects of material efficiency and resource conservation play an important role in today's discussion.

Among manufacturers, economists, scientists, politicians and other stakeholders, the material obsolescence has been a hotly debated topic for many decades. In economic history, the debate reached its climax at the end of the 1920s, in the 1960s and 1980s. On the basis of scientific and journalistic publications it can be observed that the discussions on the various forms of obsolescence have been performed for different reasons and abated after a few years. It is also observed that the discussion about obsolescence and especially about *material and functional obsolescence* has been on a rise again in the last five years. The focus of the discussion has especially been on the topic of so-called *'planned obsolescence'*. Since then, there has been a heated debate on finding a clear definition for planned obsolescence and understanding underlying objectives thereof. In popular media, planned obsolescence is defined as an intentional shortening of product life-times by integrating predetermined weak points by the manufacturer. Thereby, the main objective behind the planned obsolescence is considered as being the approach to force consumers to purchase new products to increase product sales, although the products could actually be used for a longer period. The underlying assumption is that products apart from the weak point which has caused its malfunction – has not yet reached the end of their technical lifespan.

At the beginning, primarily media reports in Germany, Austria and Switzerland were published in this regard, but in the past two years, reports have also been published in other European countries, by EU-institutions[1] as well as worldwide. Since then, various media sources (TV documentation, detailed reports in major daily and weekly newspapers) have taken up the topic on a regular basis. In France, the energy transition bill, which was passed by the national assembly on 22.07.2015, contains measures against planned obsolescence. It is foreseen to introduce a legal definition of planned obsolescence[2] and to penalize the fraud/culprit with up to 2 years of imprisonment and a fine of up to 300,000 Euros or of 5% of the annual turnover of a company. Apart from that, it is foreseen to introduce voluntary consumer information from manufacturers on the life-time of a product[3].

[1] Example: Opinion of the European Economic and Social Committee on 'Towards more sustainable consumption: industrial product lifetimes and restoring trust through consumer information' (own-initiative opinion), (2014/C 67/05). Available: http://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52013IE1904&from=DE, Accessed on 10.12.2015

[2] Article L 213-4-1 of the Codes de la Consommation defines planned obsolescence as "Programmed obsolescence is defined by each manoeuvre through which the lifetime of a good is knowingly reduced since its design stage, thereby limiting its usage time for business model reasons" (Assemblée Nationale 2015).

[3] Assemblée Nationale (2015): TEXTE ADOPTE n° 575, Projet de Loi - relatif à la transition énergétique pour la croissance verte, Article 99, http://www.assemblee-nationale.fr/14/ta/ta0575.asp; access: 24.11.2015

The requirements of the draft legislation is conditioned to be examined by the Administrative Council and not mandatory yet.

On the other hand, it is a consensus in the scientific community that the product life-time is generally a planned parameter and serves as an orientation for the product designers and developers. The planning of an optimal product life-time – from ecological and/or economical point of view – can also be considered as planned obsolescence. However, the underlying logic is in this case very different from that of the popular media discourse on planned obsolescence.

On the other hand, the *'psychological obsolescence'* tends to be relevant just as well. Here it is assumed that many consumers are rather open to novelties, appreciate innovative companies and buy new products with improved functions and utility. If there is a real need for a new product, an orientation towards innovation is a welcome option. However, many consumers tend to make new purchases, although existing products are still functioning, thus causing high resource consumption.

The aspect of reparability of products is to be understood within the concept of *'economic obsolescence'*. The concept of economic obsolescence is related not only to the technical possibilities of carrying out repairs, but also to the availability of repair service and especially incurring repair costs. Appreciation of costs between product replacements and repairs is in most cases the key factor for decisions pertaining to repairs and crucial for changing useful service life of products.

The current debate on obsolescence is dominated by a very anecdotal approach. In general, the data base on the subject of obsolescence (material, functional, psychological and economic) is incomplete, and there is an imminent need for scientific research on this topic. This study starts at this point and aims to describe various forms of obsolescence and to provide an improved data base for assessing the phenomenon of 'obsolescence', taking the example of electrical and electronic products.

Objective

The overall objective of the project is to create a sound data base for describing and assessing the phenomenon of obsolescence, trends on lifespan and usage times, and based on this, to develop strategies against obsolescence and for achieving a reliable minimum product life-time. The focus of this project is electrical and electronic equipment for use in private households.

Specifically, the following objectives will be pursued:

1. Collection of statistical data and analysis of trends on technical life- and use-times of electrical and electronic equipment;
2. Systematic description of the causes of obsolescence in electrical and electronic equipment;
3. Focus on case studies for three product groups in order to deepen the data collection and to identify measures to achieve the life-time extension or reliable service life for these selected product groups;
4. Comparative life cycle assessment and life cycle costs calculation for the three product groups selected, analysing for each one product with a shorter and one with a longer life-time;
5. Identification of cross-cutting strategies and instruments against obsolescence and for increasing product life-times as well as usage times and reaching a reliable minimum product life-time.

The overall study covers the following product groups:

- Large household appliances
  - Refrigerators
  - Freezers
  - Washing machines
  - Laundry driers
  - Dishwashers
  - Electric cookers
- Small household appliances[4]
  - Hand mixers/hand blenders
  - Kettles
- Information and communication technology Desktop PCs
  - Desktop PCs
  - Notebooks
  - Printers
  - Mobile phones/smartphones
- Consumer electronics
  - Televisions

Results of general methods for the estimation of life, use and residence time

Reproducible scientific tests, as they are carried out by the Stiftung Warentest, and several subjective experiences of consumers (e.g. on the internet platform "Murks? Nein Danke!") give important information on quality differences, repetitive quality defects, weaknesses and characteristics that limit the life-time of products. General overarching statements about the life-time of electrical and electronic equipment, however, can only partially be derived on their basis in a scientific manner.

In waste management, exact details of life-times are important for the determination of future waste quantities. These methods for data acquisition, however, need to make a trade-off between the accuracy of results and the effort for data acquisition. The evaluation of further scientific studies on the determination of life-times in the waste industry has shown, for instance, in the Netherlands that the life-time of all examined product groups has declined compared to the year 2000. However, these data do not give any indication as to whether this decline must be attributed to shorter use-times by the consumer or to shorter technical life-times.

[4] Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** contains data only for hand mixers/hand blenders. Kettles were also dealt within the cause analysis in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**. Furthermore, product tests of the Stiftung Warentest were also evaluated in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** in order to identify the main causes of defect of electrical tooth brushes, espresso machines, steam iron and vacuum cleaners.

Results of product-specific approaches to the estimation of life, use and residence time

The analysis of data of the Society for Consumer Research (GfK) for *large household appliances* in Germany show that the average first useful service-life (i.e. product used by the first user; not to be confused with technical product life-time) has declined slightly between 2004 and 2012/2013 from 14.1 to 13.0 years. The average lifespan of equipment which has been replaced due to a defect decreased from 2004 to 2012/2013 by one year and now lies at 12.5 years. On an average, the product replacement due to a defect slightly decreased between 2004 and 2012 for large household appliances, but a defect still remains the main cause of the replacement. The percentage of large household appliance replacements due to a defect accounted for 57.6% in 2004 and 55.6% in 2012 among the total product replacements. On the other hand, it is important to realize that almost one third of the replaced large household appliance was still functional. In 2012/2013, the proportion of devices that were replaced because of a desire for a better device, although the old device still worked, was 30.5% of the total product replacements. Critical is the increase in the proportion of large household appliances which have been replaced within less than 5 years due to a defect from 3.5% to 8.3% of total replacements between 2004 and 2012.

The analysis of washing machines disposed of at municipal collection points and recycling centres in 2004 and 2013 also pointed to the trend of larger numbers of large household appliances being replaced within the first 5 years of ownership. Analysis of the date of manufacture of installed capacitors put the average age of washing machines disposed of in 2013 at 13.7 years. That was significantly shorter than 2004 figures, where the average age was found to be 16 years. The age comparison also found more washing machines retained for 11 years or less in 2013. It was particularly striking that more than 10% of the washing machines in 2013 were just 5 years old or less (6% in 2004). For washing machines, further comparison of data collected at brand level revealed an identifiable reduction in the term of retention between 2004 and 2013 across virtually all brands. In the context of this data, it should be noted that the reasons for replacement are not known.

An online consumer survey conducted by the University of Bonn in 2013/2014 furthermore revealed the average age of washing machines disposed of by survey participants to be 11.6 years. 50% of the washing machines disposed of were up to 10 years old. The reason for disposal was a defect in 69 percent of cases. In 10 percent of cases, the washing machines were not sufficiently efficient.

The analysis of the data collected for *small household appliances* showed that the average first useful service-life of electric hand blenders and hand mixers has marginally changed over the years. The first useful service-life for both products has been 10.6 years in 2012. Considering the development of the first useful service-life of both product types separately, it is revealed that electric hand mixers show a slight decline from 12.1 years to 11.0 years in 2012. Thus, they lie more or less at the same level as hand blenders, as far as their first useful service life is concerned. Hand blenders have shown an average first useful service life of 10 years, regardless of the main buying reason.

The online consumer survey conducted by the University of Bonn in 2013/2014 more or less corroborates the analysis of hand mixers described above. The results of the online consumer survey show that consumers use hand mixers on average for 10 years before disposing them. 50% of hand mixers disposed of was up to 8 years old. According to the survey respondents, the hand mixers were disposed of due to a defect in most cases (76.2%). Comparison with a further survey conducted in 2014 looking at the reasons for disposing of hand mixers at a municipal collection point shows an interesting reading in this regard. In this study, the presumed reason for disposal was a fault with the device's housing in 9% of cases, while for 35% of the hand mixers, the issue concerned a technical defect. In 52% of cases, the reason for disposal was not clear, as no faults at all could be found in terms of the technology, mechanism or design. In this respect, the two surveys reveal quite a different picture as regards the reasons for disposing of hand mixers.

Kettles disposed of according to the online consumer survey of the University of Bonn were aged on average just 5.7 years. Half of those were just 5 years old. 68 percent of the kettles were disposed of due to a defect according to the survey respondents. Comparison with the study investigating kettles disposed of at the collection point in 2014 also shows an interesting reading in this regard. According to this study, 17.9% of the devices were likely disposed of due to a mechanical defect in the housing. In 28.6% of the devices, a technical defect causing loss of functionality was the presumed reason. In this respect too, the results of the online consumer survey differ from those of the study at municipal collection points.

In the area of *consumer electronics*, flat screen TVs showed an average first useful service life of 5.7 years in 2007. This value decreased to 4.4 years in 2010. In subsequent years (until 2012), the average first useful service life of flat screen TVs increased again continuously to 5.6 years. It is noted that the average first useful service life of replaced flat screen TVs is significantly lower than that of the CRT TVs that are replaced at the same time. The results also show that in 2012, over 60% of the functioning flat screen TVs were replaced because consumers wanted to have a better device. The average lifespan of flat screens which were replaced due to a defect was 5.2 years in 2009. It decreased to 4.6 years in 2010 and rose to 5.2 and 5.9 years in 2011 and 2012, respectively. It can be noted that the proportion of product replacements of defect flat-screen TVs decreased slightly between 2008 and 2012 from 28% to 25%.

The results of the online consumer survey conducted by the University of Bonn in 2013/2014 showed the average age of television sets disposed of to be 10 years. The result though is attributable to the fact that no distinction was made in the online consumer survey between CRT TV and flat screen sets. One can therefore assume that CRT television sets accounted for an appreciable proportion of the online survey outcomes. The results furthermore reveal that 50% of television sets disposed of was no older than 10 years. 44 percent of the sets were disposed of due to a defect according to the survey respondents. From the opposite perspective, this means that 56% of the TV sets were disposed of despite most likely functioning.

In the field of *information and communication technology*, the example of notebooks shows that the average first useful service life increased from 5.4 years (2004) to 6 years (2005/2006) and decreased slightly to 5.7 years in 2007. In 2012, the average first useful service life of notebooks further decreased to 5.1 years. The average lifespan of notebooks which were replaced due to a defect rose between 2004 and 2006 from 4.8 to 6.5 years and decreased again in 2007 to 5.3 years. In the years 2010-2012, the average lifespan of defect notebooks was between 5.4 and 5.7 years. A clear trend that notebooks break sooner over the time cannot be confirmed from the data. However, it is noted that replacement due to a defect accounted over 25% of all replacements in 2012/2013. Those notebooks which were replaced because they were faulty and unreliable were aged 4.8 years on average in 2004. In the period up to 2012, the average life of these devices increased to 6.0 years in 2011 and 6.2 years in 2012. This trend indicates a decreasing susceptibility of the notebook computers to failures in the course of time between 2004 and 2012. The average useful service life of the functioning notebooks that were replaced because of the desire for a better device was approx. 6 years between 2004 and 2012. A clear trend in the terms of an extension or shortening of the average useful service life cannot be derived from the data. However, it can be stated that the product replacement due to a desire for a better notebook has been decreasing over the years between 2004 and 2012/2013.

The online consumer survey of 2013/2014 showed that the average age of notebook computers disposed of was just 4.9 years. 50 percent of the notebooks in the survey were up to 5 years old. In 46 percent of cases, old notebooks were disposed of due to being defective. 25 percent of notebooks were replaced due to having too limited functionality.

Systematic description of the causes of obsolescence

Building on the analysis of the service and usage life of electric and electronic devices, the causes of obsolescence have been assessed and systemised according to four categories: (1) material obsolescence, (2) functional obsolescence, (3) psychological obsolescence, and (4) economic obsolescence (see Section 3 for definitions). This involved identifying the typically prevalent factors, characteristics and components that brought about the end of the respective periods of usage. In particular for life time-limiting factors identified in the context of material obsolescence, it was researched whether the end of the period of usage could be attributed to specific wear parts. In terms of functional obsolescence, focus was on analysing the influence of software-induced factors, such as operating system and driver updates and changes in standardization landscape and the media-political environment (e.g. new formats, new functions, new transmission standards etc.). In terms of repair works, economic obsolescence, i.e. the comparison of the cost of repair with the cost of buying a new product, was more closely analysed for all device groups. Psychological obsolescence was described in detail for those product groups that stood out as example products for this type of obsolescence in the preceding analysis of lifespan and usage times (e.g. television sets and smartphones). In attempts to analyse and systematise the causes of obsolescence, a comprehensive assessment of scientific studies and of independent products tests was undertaken. A survey of numerous experts was also performed, including product manufacturers, test institutes, repair and re-use businesses, academic institutions in the materials sciences and design fields, standards and standardization institutions and consumer organisations.

Analysis of the causes of obsolescence has shown that the devices examined are replaced for a wide variety of reasons. Material, functional, psychological and economic factors of obsolescence were shown to be jointly influential and draw somewhat a highly complex picture. Usually, even the causes of material obsolescence are highly varied and thus pinpointing any one specific cause is difficult. Generally, it has been observed that virtually any part or component of a device may be the one to fail. However, there are some components and parts that are relatively more likely to fail and thus can be said to have an impact on limiting life-time.

For *television sets*, the analysis identified the chief causes of material obsolescence to be the display/screen unit, power board, aluminium electrolytic capacitors and damage to delicate components resulting from transport. On the other hand, many other components, though relatively less likely, were found to be at risk of failing too, such as main boards. Material obsolescence does not represent the primary problem for TV sets according to the surveyed experts. The chief cause of the failure of television sets is attributable to software-induced faults, i.e. to functional obsolescence. However, the most important reason for why older television sets are replaced by newer models is attributed to psychological obsolescence. The study showed that over 60% of the still fully functional flat screen TVs were replaced in 2012 because their owners desired a better device. Key factors in replacing a television set were found to be the need for a larger screen size and better picture quality, as well as falling prices. Defects are clearly an important reason, though rarely decisive when it comes to TV set replacement.

In the case of functional obsolescence, the rapid pace of development of TV technology in terms of resolution, new functionalities and the lack of standardisation with regard to transmission standards play a significant role. The development of new TV formats has led in recent years to older devices lacking the necessary hardware chips (transmitter and receiver chips) to be able to handle the corresponding new formats or to render the transmitted content in the desired quality. Furthermore, new functionalities (e.g. the fusion of television and internet in the form of hybrid TVs (HbbTV)) place significantly higher requirements on software. If the software used does not have a modular structure and the devices lack a scalable memory, older devices are quickly pushed to their limits due to the new content and functions. The increasing volume of source data (i.e. the quantity of underlying source code), which has grown in recent years from approx. 1 MB to over 100 MB due to the launch of SMART TVs, should not be underestimated. In order to test the full source code for errors, i.e. to perform a "full test", one would need around 15 work weeks. As product innovation cycles in the industry are very short (cycle time of 1 year), however, the source code is not tested in its entirety in many cases; rather often only typical fault possibilities are reviewed and the general likelihoods of failure derived based on statistical procedures ("regression"). Some manufacturers are known to reduce the durations of testing to around 3 weeks. An issue in this respect, however, is that the software is not tested for functionality in its entirety, which can produce software errors.

One of the reasons why the first useful service life of defective television sets or the age of many scrapped television sets is at a relatively low level is no doubt due to economic obsolescence. The costs involved in repairing components often prone to failure such as the display and screen unit and power board run into the hundreds of euro. In view of generally falling sales prices for TV appliances, consumers may consequently choose to purchase a new device instead of having a defective set repaired.

For *smartphones/mobile phones*, the online repair platform iFixit (www.ifixit.com) was closely examined. For the smartphone models investigated, frequent causes of repairs included the battery, screen unit, home button and power button. The potential for failure of many other components was also observed.

The frequent need to repair or replace the battery in smartphones may be due to the increasing intensity of use and range of functions of these devices. Assuming that the replaceability and/or exchangeability of batteries are decisive for the extended use of a smartphone, the iFixit platform's battery disassembly analyses were looked at. This showed that it was possible to remove the battery in models without permanently fitted battery in less than a minute. On two models with permanently fitted batteries, however, battery removal required 15-20 minutes as well as a range of special tools. Research by the leading German consumer testing organisation, Stiftung Warentest, reveals that the proportion of mobile phones with permanently integrated batteries grew consistently between 2010 and 2013. Almost 36% of mobile phones examined by the organisation in 2013 had a permanently fitted battery. Stiftung Warentest tested further smartphones in an additional test in 2014, finding approx. 35% of the devices to have a nonreplaceable battery. The tests included several models that received a poorer quality rating in terms of battery performance. Due to the fact that users are unable to replace some batteries and that battery performance is inadequate, it seems likely that these models will end up being replaced in the course of their utilisation due to poor battery performance.

A further investigation conducted by Stiftung Warentest, however, shows that just 9% of respondents who changed their mobile phone after a period of less than 3 years cited a battery defect or weak battery performance as the reason for doing so. 68% of respondents on the contrary stated that they change their mobile phone after periods of less than 3 years either because they desire an even better device (40%) or because they regularly receive a new phone through their contract (28%), i.e. psychological obsolescence. Furthermore, other surveys by Stiftung Warentest reveal that 42% of users in Germany replace their mobile phone after a period of less than 2 years. Approx. 16% of users replace their mobile phones every three years. It can be stated in summary that psychological obsolescence plays the leading role in limiting the usage duration of smartphones/mobile phones.

For *notebooks*, analyses of material obsolescence reveal failure to be a potential issue for the following components of devices for private consumers (consumer notebooks): hard disc drives, memories, graphics chips and batteries (very commonly), and main boards, processor fans, power supplies, peripheral interfaces, screen and screen lids (hinges) and notebook housings (commonly). It is interesting to note that devices used for business purposes (business notebooks) differ to consumer notebooks when it comes to the likelihood of failure of components. On business notebooks, hard disc drives and batteries are shown to fail frequently, though all other components were mentioned to fail rarely. Principle reasons for the likelihood of failure are thermal issues, mechanical wear and careless handling. Furthermore, permanently fitted batteries, soldered-in memory device components and permanently fitted hard drives should be considered life time-limiting factors. Moreover, the life-time of installed electrical and electronic components (e.g. aluminium electrolytic capacitors) and assemblies is greatly dependent on the dimensioning of the components and their thermal exposure.

Participants in the online consumer survey indicated with respect to the proportion of defective notebooks that the battery was to blame for the failure in approx. a third of cases, followed by the main board (approx. 23%), screen and fan (approx. 19% each) and graphics card (13%). Further studies and independent product tests show that hinges on device lids and other exposed or undersized component connections subjected to high loads represent a problem. Unintentional shocks or dropping or even continuous stress conditions (e.g. hard drive and permanently fitted PCB components) lead to defects or to devices failing. A further study (SquareTrade 2009) concluded that 20.4% of the notebooks examined had failed due to hardware faults within the first three years of use and a further 10.6% of devices due to accidents and improper use in the same period. A study by British research institute WRAP on notebooks found that 7% of devices fail in the first year, a little fewer than 20% in the second year and a third of devices after just the third year.

In terms of the interaction between functional obsolescence and hardware drivers, manufacturers of peripheral devices in particular are called upon to provide drivers for longer periods as the support and development cycles of operating systems and changes of driver architecture are announced in the long term. Functional obsolescence, which is brought on by updates to an operating system, has in the past resulted in older PCs being unable to meet the minimum requirements of the new operating system. Furthermore, the discontinuation of support for older operating systems has led to scenarios where security-relevant updates for operating system and software were no longer available, impeding protection against Trojan and viruses. As a consequence, hardware had to be replaced or an entirely new PC procured, even though the technical life-time of the original equipment was not yet up. The discontinuation of Windows XP resulted in the need to replace a large number of outdated yet fully functioning desktop PCs and notebooks worldwide. The operating system had been supported, however, for almost 13 years. Installing a current Windows operating system (Windows 7 or higher) likewise is not something that could be done on many older desktop PCs and notebooks. This is usually less of a problem, however, for computers that are just a few years old.

The analysis further suggests meanwhile that psychological obsolescence now plays less of a role for notebooks. This seems to indicate that the symbolic significance of notebooks as a fashion accessory or as a status symbol has waned. At the same time, innovation cycles can also be assumed to have slowed and development efforts channelled elsewhere (e.g. tablet computers).

Permanently fitted batteries and special bolts in front of motherboards, memory devices or hard discs, which can only be opened using special tools, are a cause of economic obsolescence amongst other consequences. Replacing the main board, processor or graphics chip on a notebook attracts the greatest costs when it comes to repair. In these cases, it can be assumed that consumers would often favour purchasing new devices over arranging repairs. Costs associated with upgrading or replacing memory devices, fans, hard discs, batteries and on some devices the screen are somewhat less.

To investigate the causes of obsolescence with regard to *washing machines*, the results of lifetime studies conducted by Stiftung Warentest over the last 15 years (2000-2014) were analysed for the issues identified to restrict the life-time of these devices. The tests encompassed 196 different models of washing machines, with around 600 devices in total. Out of 196 models, 41 models encountered problems during the test for a 10-year usage, leading to a rating of poor/inadequate for product life-time. Analysis of the causes of failure showed few recurring failures. Virtually every washing machine component was identified as a cause of failure. Components subject to increased vibration load in particular (all parts attached to the tub), however, seemed to fail more often than others. Research conducted by British institute WRAP similarly reveals a range of factors that may limit the life-time of washing machines. Principle causes identified included issues with the electronics, the door seal and hinge, feed and drain piping, water heating element, drum container, motor and detergent drawer. Respondents in the online consumer survey cited an electrical fault (28%), followed by a pump fault (23%) and storage damage (15%) as the primary reasons for failure.

Experts surveyed as part of the study also stressed the risks of failure associated with reducing the structural size of semiconductors and the rapid increase in the integration density of storable data on semiconductors. In many cases, however, available electronic component variants offer contrasting likelihoods of failure depending on conditions of use (in particular temperature). It is generally possible to subject components and integrated circuits to more elaborate testing in order to identify and rectify potential causes of failure, though cost is a factor in this. On the other hand, it is also important to understand that the use of electronic sensors and microprocessors for controlling or regulating purposes allows much smaller spacing to be used and thus allows for the integration of functions in a semiconductor chip or on a board on a much broader scale. Many plug contacts between individual components are also done away with and thus the potential for faults in this respect is diminished. Furthermore, integration on one component facilitates a much more advanced assessment of the functionality of the component before being installed in a device.

A connection also exists between functional obsolescence in the context of washing machines and the development and use of detergents and textiles. Older washing machines may indeed retain their full functionality, though their ability to use modern detergents in a resource-efficient manner and to care for modern textiles optimally is restricted. Older washing machines could be seen to need much more power to achieve good washing performance. In fact, at the time of performing the tests in 2004, to achieve the same washing effect as new machines on a 40°C wash, old machines had to be run at 90°C. Furthermore, the washing effect of older washing machines at 40°C was far below that of newer devices. The studies (2004) showed that a new machine needed around just half of the power that a 15-year-old machine required and a quarter of the power that a 30-year-old machine required to achieve the same washing performance. Comparison of water consumption at constant load revealed similar indicators of improvement over time. Washing machines, textiles and detergents are expected to develop further in future too. The reality that today's modern washing machines in one or two decades may be unable to offer optimal performance with the detergents and textiles of the future consequently can't be discounted. The online consumer survey seems to indicate that these effects of functional obsolescence were the reason for purchasing a new washing machine for around 12% of households.

The analysis of economic obsolescence in the case of washing machines again confirmed the high costs of repair as a potential obstacle. It is theoretically possible to repair any failed assembly or component in a washing machine, though the costs of doing so can be exceedingly steep. In particular, this is due to the fact that such repairs are performed on location, meaning call-out charges for servicing personnel are incurred. Together with replacement parts costs, for some repairs, such as to control electronics, motor, detergent solution container and ball bearings, costs can run into the several hundreds of euro. On the other hand, market prices for new washing machines have fallen sharply, in particular in the run up to 2004.

Planning product life-times

Reports in the media in recent years have honed in on the issue of "planned obsolescence" with great fervour, dividing society into two opposing camps, specifically that of manufacturers and industry as the "culprits" and that of consumers as the "victims" of obsolescence. The study has shown the phenomenon of the obsolescence of products not to be so one-dimensional. Manufacturers and consumers interact with one another in a continuously changing environment and mutually influence product development and consumption patterns.

In the context of things, there is essentially no disagreement when it comes to the question as to whether manufacturers plan the life-times of their products. The product life-time is generally a planned parameter and serves as an orientation for the product designers and developers. The planning of a product life-time is, however, dependent upon many factors, such as stress, abrasion stock, maintenance, technological change, fashion, shift in values and other external environmental influences. Ideally, the aim is to achieve an optimum where the product lifetime is equivalent to product usage time. In order to achieve this optimum, components have to be construed in a way so that all components reach (more or less) a similar time-interval in terms of their life-time. Such a construction is considered to be more cost-effective as it avoids unnecessary abrasion stocks. The core principle is to construe products to last as long as necessary and not as long as possible. Therefore, product requirements have to be seen in the context of specific user profiles and user environment. Precisely, it means that planning pertaining to the product life-time is dependent upon the objectives and target groups as well as future market and technology development scenarios. The requirements are, therefore, different for different products – an aspect which is generally communicated within the sales prices. The requirements are also influenced by other factors, such as service-delivery, availability of spare parts, additional functions, design, updates, reparability, mechanical and electrical robustness etc. What lies behind the decisions of companies, however, is not something consumers are privy to. The lack of transparency leaves consumers unable to make the best buying decisions as regards their own needs (asymmetrical information).

The study's analyses could not confirm planned obsolescence as regards to manufacturers intentionally manipulating designs or knowingly integrating weak points. Nevertheless, this was not the primary aim of the study in any case. The study looked more closely at three typical cases swooped on by the media as prime examples of planned obsolescence in terms of wilful design manipulation: (1) aluminium electrolytic capacitors, (2) plastic tubs in washing machines and (3) ink pad reservoirs in ink-jet printers. In all three cases, allegations of planned obsolescence in terms of wilful design manipulation failed to stand up.

In the case of *aluminium electrolytic capacitors*, the fact that these, as temperature-sensitive components, are placed in close proximity to heat sources was found to be problematic. Due to technical and physical conditions, however, they have to be placed there to ensure the functionality of the device. Only by positioning the capacitors close to the processor base, the electrical series resistance can be kept low and the dynamic properties of the circuit be improved. The issue therefore concerns a design decision demanding a well-rounded compromise of priorities as regards differently focussed principles of action. On the other hand, correctly sizing electrolytic capacitors is undoubtedly something that concerns the product life-time. The choice of electrolytic capacitors is made according to economic principles in the course of a complex product development process in which the expected life and usage time forms the basis for product design. If real-life operating conditions, however, differ to those used as the basis in selecting the electrolytic capacitors, the electrolytic capacitors may lead to premature product failure as life-time limiting components. Quality shortfalls in the supply chain may likewise play a part. For these reasons, it is worth implementing stringent quality management processes in the supply chain alongside minimum requirements around the dimensioning of electrolytic capacitors and the formulation of realistic operating conditions for function testing. The additional expense resulting from this for device manufacturers does not appear significant in view of the ecological benefits of extended life-time.

In terms of the use of *plastic tub* in washing machines, the plastic material offers a host of additional benefits (e.g. noise characteristics, thermal losses, corrosion) in addition to cost advantages compared to containers produced from stainless steel. However, sufficient expertise is key around the structural design of high-load plastic components, in particular in terms of structural mechanics, chemical resistance and thermal stress properties. The independent studies conducted by Stiftung Warentest examining the life-time of washing machines over the last 15 years involving around 600 machines (196 models, three devices per test) revealed that just a few of the appliances had problems attributable to a plastic tub. This is assuming around 90% of the devices tested featured a plastic tub. Stiftung Warentest, however, has so far only tested devices in price categories above € 350.

In terms of *ink pad reservoirs*, the identified problem is related to a protective function. The error message and/or ceasing of function that appears after a specific number of printed pages is intended to prevent possible secondary problems, such as contamination due to leaking of ink, when the capacity of the ink pad reservoir is reached. Critical examination of the protection mechanisms, however, nonetheless reveals that leak protection can be achieved by other technical means without ceasing the function of the entire appliance. Replaceable residual ink containers are used and can be found in models from the mid-range price category and above. A further point of criticism is the fact that this limited capacity of the ink pad reservoir is often not known to consumers on purchase.

As a conclusion, it can be derived that the more precisely manufacturers perform their life-time tests, the more precisely they adapt their test conditions to real-life conditions of use and the more precisely they review quality standards in the supply chain, the more confident they can be in making statements concerning expected life-times, i.e. the likelihood of a specific life-time being reached or the likelihood and frequency of certain components failing. On the other hand, it is clear that rapid product cycles, shrinking product prices and the cost and time-intensive nature of life-time testing have had a significant effect on the time dedicated to the practical application of life-time tests, with sometimes only the most important functions subject to review. This has left manufacturers themselves quite unable to provide absolutely concrete data on the life-times of their products.

To prove or refute the allegation that manufacturers knowingly design certain components in such a way as to ensure they fail due to a defect after a predefined period of time in order to force consumers to buy new products was not the primary aim of this study. The purpose of the study rather was to analyse trends associated with service and usage life, the causes of product failure and the reasons for replacing products. The analysis has revealed that in reality there are very diverse reasons for why products are replaced. It has been shown, however, that devices more and more are replaced or otherwise disposed of after shorter periods of use. This practice is unacceptable from ecological considerations.

Ecological and economical comparative calculation between short- and long-life products

This study involved undertaking ecological and economical comparative calculations between short- and long-life product variants for washing machines, television sets and notebooks. The outcomes of the ecological comparative calculation paint a clear picture. In all product groups investigated, long-life products do better than short-life variants in all environmental categories. This remains the case even having considered retrofitting options/repairs to long-life products with replacement parts (including their manufacturing impact) alongside the enhanced energy efficiency of new devices and the higher manufacturing impact of the long-life product.

For *washing machines*, the cumulative energy demand and the global warming potential of a short-life washing machine (life-time of 5 years) are approx. 40% higher compared to a long-life washing machine (life-time of 20 years). Over a given period of 20 years, a long-life washing machine produces almost 1100 kg less CO_2e than the short-life variant. The acidification potential of a short-life washing machine is approx. 60% higher compared to the long-life washing machine. The difference between a long-life washing machine and an average washing machine (life-time of 10 years) is considerably less acute; the long-life washing machine, however, nonetheless performs better in most environmental categories (e.g. 12% less global warming potential and 18% less acidification potential).

For *television sets*, the acidification potential is 42% higher for a short-life set (life-time of 5.6 years) compared to the long-life variant (life-time of 10 years). The cumulative energy demand of a short-life television set is 28% higher and the global warming potential is 25% higher compared to a long-life television set. Over a given period of 10 years, a long-life television set produces almost 600 kg less CO_2e than the short-life variant.

For *notebooks*, the long-life product (life-time of 6 years) produces almost 300 kg less CO_2e than the short-life variant over a given period of 12 years. The acidification potential environmental indicator is 49% higher for a short-life notebook (life-time of 3 years) compared to the long-life variant. The cumulative energy demand of a short-life notebook is 25% higher and the global warming potential is 36% higher compared to a long-life notebook.

The economical comparative calculations between short- and long-life product variants were undertaken following the life cycle costs approach. Assumptions made in this regard concerning the costs of purchase play a significant role and influence the outcomes heavily. The difference in purchase costs between short-life and long-life product variants is a decisive variable that determines the cost savings effects or additional costs of a long-life product in comparison to a short-life product. If the difference is small, positive cost savings effects would usually be more substantial for long-life products. On the other hand, the long-life product would do less favourably in terms of life cycle costs or its positive cost savings effects would be less if its costs of purchase were significantly higher than a short-life variant. The estimated boost in energy efficiency and costs of repair and replacement parts also play an important role. If the energy efficiency of newly purchased short-life products is considerably better than that of predecessor generations, and the difference significant in terms of the costs of purchase between short-life and long-life variants and in terms of the costs of repair, negative cost effects would usually manifest with respect to long-life products.

The calculations performed in the course of this study reveal the annual total costs of a long-life *washing machine* with 20-year life-time to be the least. In contrast, a short-life washing machine with a 5-year life-time produces approx. 13% higher costs. Compared to a short-life washing machine, by buying a long-life washing machine, approx. € 283 can be saved per device over a 20-year period. A long-life washing machine, according to the assumptions made in this study, would need to be priced around 270% higher than the short-life variant in order to surpass the life cycle costs of the short-life washing machine.

For a long-life *television set* that does not need to be repaired during its 10-year life-time, the annual total costs are less compared to the short-life variant. The difference, however, to the short-life variant (life-time of 5.6 years) is almost negligible. It is striking that the annual total costs of a short-life TV set are lower than those of a long-life TV set that needs to be repaired during its life-time. The relatively high costs associated with the long-life TV set in this example calculation are attributable to the high costs of repair in addition to the high purchase price. A long-life TV set (without repairs), according to the assumptions made in this study, would need to be priced around 75% higher than the short-life variant in order to surpass the life cycle costs of the short-life TV set.

For a long-life *Laptop* that does not need to be repaired during its 6-year life-time, the annual total costs are less than those of the short-life variant. The annual total costs of a long-lasting notebook that needs to be repeatedly repaired in order to achieve a six-year life-time are higher than those of a short-life notebook (life-time of 3 years) due to the high costs of repair. Compared to a short-life notebook, by buying a long-life notebook that does not need repairing, approx. € 196 can be saved per device over a 12-year period. In the case that a long-life notebook would need repairing, additional costs of approx. € 261 would be incurred over the same period when compared to the short-life variant. A long-life notebook (without repairs), according to the assumptions made in this study, would need to be priced almost double that of the short-life variant in order to surpass the life cycle costs of the short-life notebook.

Strategies to counter obsolescence

This study sought to develop strategies to counter the obsolescence of electrical and electronic devices based on the analysis of causes. The focus in this respect was on *technical, product-specific and management-related strategies and solutions*. The principle objective was to achieve a reliable minimum life-time or to extend the term of use of electrical and electronic devices. The process involved consolidating and grouping the causes of failure and replacement in superordinate issue clusters. This allowed strategies to be defined to address issue clusters as a whole and thus the varied product groups and causes of obsolescence assigned to these, independent of the specific product group or of each individual reason for replacement. The issue clusters and the causes of the failure and replacement of washing machines, notebooks and television sets assigned to these are depicted in the following Table 1. The full range of identified causes can be divided into a total of 4 main issue clusters. The identified causes of failure and replacement for the product groups “washing machines”, “notebooks” and “television sets” have been allocated to these issue clusters. Assignment along these lines produced a conducive overview of the causes of obsolescence that apply equally to all of the product groups examined and which may be addressed by means of horizontal product group-spanning strategies, and of the causes of obsolescence that require product group-specific solution approaches.

Table 1 Description and allocation of the causes of obsolescence

	Issue cluster for causes of obsolescence	Washing machines	Notebooks	TV sets
1	**Deficient mechanical and electronic robustness (material obsolescence)**			
1.1	Targets delivered to production for life-time to be achieved not available or too brief. The lack of transparency leaves consumers unable to make the best buying decisions as regards their own needs (asymmetrical information).	X	X	X
1.2	Components are not sufficiently checked for adherence to life-time requirements during production or at the approval stage.	X	X	X
1.3	Real time stress exposure is beyond benchmark life-time requirements implemented in production.	X	X	X
1.4	The device as a whole is not sufficiently checked for adherence to life-time requirements.	X	X	X
1.5	Various production series of the same devices contain different components. High competitive pressure creates volatility in the availability and quality of components. The quality standards of manufacturers, if existing at all, cannot be implemented vertically into supply chains.	X	X	X
1.6	Poor device design and heat management, e.g. ventilation slots that are blocked by dust and dirt particles and lead to the device overheating.		X	X
1.7	Short battery service life (useful life and capacity) limits use (electrochemical robustness); permanently fitted batteries make it difficult or impossible to replace.		X	
2	**Software-induced reasons (functional obsolescence]**			
2.1	New TV formats appearing frequently (e.g. HD Ready, Full HD, UHD), new functionalities (e.g. HbbTV) and the resulting increase in source data place greater requirements on both software and hardware.			X
2.2	Different transmission standards, a lack of standardisation of dynamic channel management and interfaces and conditional access systems.			X
2.3	For older components and peripheral devices (e.g. some graphics cards, printers and scanners), manufacturers often stop releasing updated		X	

Issue cluster for causes of obsolescence		Washing machines	Notebooks	TV sets
	drivers for current operating systems, meaning that these can no longer be used as had been the case or at all.			
2.4	Installing an up-to-date operating system on older notebooks may no longer be possible due to their performance restrictions. If the minimum requirements of the operating system are not met, the operating system will be unable to run on the hardware in question and this would need replacing despite not having yet reached its technical end of life.		X	
3	**High cost of repair in the context of new product pricing (economic obsolescence)**			
3.1	For many defects, the costs of professional repairs seem too expensive in view of the current market prices for new products.	X	X	X
3.2	Excessive component integration, meaning replacement is complex and accordingly expensive. Furthermore, poor accessibility of components.	X	X	X
3.3	No replacement parts or only original parts available.	X	X	X
3.4	Excessive call-out fee for servicing technicians.	X		(X)
4	**Trends and desire for new functionalities (psychological obsolescence)**			
4.1	Innovative features, new functionalities and promises of convenience in new devices lead customers to buy new products.	X	X	X
4.2	Socio-demographic factors, such as moving to a new apartment with fitted kitchen or passing down existing devices to younger family members.	X	X	X
4.3	Enhanced energy efficiency of new devices, e.g. replacing a desktop PC with a notebook.	X	X	X

Strategies to counter the causes of failure and replacement identified in Table 1 are proposed in Table 2. The aim is to address all of the causes of failure and replacement assigned to an issue cluster with the same strategies.[5] The individual strategies to counter obsolescence are presented in greater detail in Section **Fehler! Verweisquelle konnte nicht gefunden werden.** (Tables 106 to 110). A brief appraisal of possible strengths and weaknesses is furthermore included for each strategy. Potential product-political instruments that may be suitable for implementing the respective strategies have also been highlighted.

[5] The development of strategies intended to counter the causes issue cluster *"Trends and desire for new functionalities"* is not included in this project. For this group of issues, the German Federal Environment Agency has commissioned other projects dealing with the topics of social innovation and cultural change.

Table 2 Identification of strategies to counter obsolescence

Causes of obsolescence issue cluster		Strategies to counter obsolescence	
1	Deficient mechanical and electronic robustness	**Strategy 1: Life-time requirements, standardisation, standards definition**	
		S 1.1	Support of voluntary life-time tests using corresponding test standards and under critical test conditions
		S 1.2	Compulsory life-time tests under critical test conditions and specification of life-time in technical documentation and/or as part of consumer information
		S 1.3	Development of testing methods and standards for reviewing the life-time testing of components and devices
		S 1.4	Investigation of the influence of real-life usage conditions on life-time and establishment of a standard with critical test conditions
		S 1.5	Design for longevity
		S 1.6	Additional testing of life-time by independent test institutes, such as Stiftung Warentest
2	Software-induced reasons	**Strategy 2: Minimum requirements on software**	
		S 2.1	Development of innovative and modular software solutions
		S 2.2	Essential software drivers must be kept available and updated for a sufficiently long period
		S 2.3	Promotion of free-standing software and hardware initiatives and creation of legal framework for their use and commercialisation
		S 2.4	Compulsory hardware and software updates and full functionality tests
		S 2.5	Standardisation, fault diagnostics function and new software solutions
3	High cost of repair in the context of new product pricing	**Strategy 3: Reparability**	
		S 3.1	Improved framework conditions for independent and free-standing repair companies, including transparent repair information
		S 3.2	Mandatory specifications for maintaining availability of spare parts, including transparent information concerning anticipated costs of spare parts
		S 3.3	Batteries and other wear parts must be easy to replace or repair
		S 3.4	Changes to cost calculation for repairs
		Strategy 4: Servicing models of manufacturers for extending life and usage time	
		S 4.1	Leasing models (as ownership-substituting utilisation strategy)
		S 4.2	Buy-back agreements
		S 4.3	Aftercare treatment as a service
4	General: shorter usage periods by consumers	**Strategy 5: Information obligations, consumer information**	
		S 5.1	Clear declaration of predetermined breaking points (in terms of functional safety), wear parts and maintenance intervals
		S 5.2	Consumer information on extending usage periods

In due consideration of further technological development and innovation with respect to electrical and electronic devices, *minimum requirements for product life-time and quality* represent an important strategy independent of product design and the product group. In view of the fact too that in many cases economic obsolescence leads or can lead to the end of a product's use, a reliable product life-time, during which repairs are not necessary or needed only in the rarest of cases, seems the right course. To be able to reliably develop and effectively review such minimum requirements, norms and measurement standards are called for. A number of standards and norms indeed already exist for the components used for reviewing the safety and suitability for use of electrical and electronic devices. Life time-specific tests for products, however, are lacking. The development of suitable test standards is indeed possible, but requires a lot of time (30-60 months) and financial resources. On the other hand, existing measurement standards and norms at component level provide a good starting point, though many of these have been developed primarily to review the safety and suitability for use of electrical and electronic devices. The utilisation and adaptation of measurement standards and norms at component level, however, may also be wise given that product-specific life-time tests are not implementable in practice for all products or are associated with extremely high costs and time outlay. It is important, however, that devices are designed in accordance with the real-life constraints of their application. Deviations in this respect can easily lead to overloading and consequently premature failure. The *"Life-time requirements, standardisation and standards definition"* strategy consequently represents the core of the superordinate strategies to counter obsolescence.

Furthermore, *innovative service models* of manufacturers (e.g. leasing, buy-back agreements or aftercare treatment) and compulsory *minimum requirements on software* may help technical product life-times to be achieved in practice (e.g. through reconditioning for further use/reuse, guaranteed repairs by manufacturers or enhanced coordination of software and hardware solutions). Measures to *improve consumer information* (e.g. ecological benefits of long-life products) and to *increase the information obligations of manufacturers* (e.g. clear declaration of wear parts) are further important tools in swaying buyers towards long-life products.

The analysis of economic obsolescence in this study has shown a risk of low willingness to repair devices in many cases due to high replacement part and labour costs and falling prices for new products. In addition, increasing product complexity and high integration densities in modern products and remote-controlled software-induced fault diagnostics have created major challenges for independent, non-manufacturer-associated repair businesses. Through a *strategy intended to improve reparability*, it may be possible to create, amongst other things, better framework conditions for the reparability of products and to maintain the independent repair scene in Europe. The likelihood of such a strategy succeeding in terms of the challenges discussed above, however, still needs to be looked at. It is important in terms of environmental considerations that repairs are possible and sought by end customers. What is more important, however, is that there are minimum quality standards and dependable life-time tests and specifications for products so that repairs are rarely necessary, if ever.

The strategies proposed in this study to counter obsolescence are intended to remedy the information asymmetries between manufacturers and consumers concerning expected product life-times and usage intensities. The proposed strategies, above all, are intended to oblige manufacturers and the political establishment to increase transparency concerning expected product life-times and to stipulate minimum durability and quality requirements for products, parts and components. On the other hand, consumers too are called on to use products for as long as possible in efforts to preserve resources and the environment. Strategies to counter obsolescence accordingly cannot be implemented overnight. Rather, they should be seen as a duty for society as a whole through cooperation between policy makers, manufacturers, the scientific community and consumers.

Zusammenfassung

Hintergrund

Produkte der hochtechnisierten Dienstleistungsgesellschaft des 21. Jahrhunderts verursachen unter anderem durch zwei Gegebenheiten signifikante Umweltauswirkungen: Erstens steigt die Anzahl der Produkte selbst stetig an und zweitens sind teilweise relativ kurze Nutzungsdauern zu beobachten.

Das daraus resultierende Abfallaufkommen von Elektro- und Elektronikgeräten sowie eine immer kürzere Lebens- oder Nutzungsdauer von Produkten werden in der Öffentlichkeit aktuell immer häufiger mit einer Erscheinung in Verbindung gebracht, die in Fachkreisen als *„Obsoleszenz"* bezeichnet wird. Während in den früheren Diskussionen zur Obsoleszenz in den 1960er und 1980er Jahren die zur Verfügung stehende Menge an Ressourcen als nahezu unbegrenzt angesehen und die unterschiedliche Anzahl eingesetzter Stoffe in Produkten als eher gering eingeschätzt wurde, spielen Aspekte der Materialeffizienz und Ressourcenschonung in der heutigen Diskussion eine wichtige Rolle.

Unter Herstellern, Ökonomen, Wissenschaftlern, Politikern und anderen Interessierten ist die werkstoffliche Obsoleszenz seit vielen Jahrzehnten ein intensiv diskutiertes Thema. Wirtschaftsgeschichtlich entwickelten sich Ende der 1920er Jahre, in den 1960er und 1980er Jahren Diskussionshöhepunkte. Anhand von wissenschaftlichen und journalistischen Publikationen ist zu beobachten, dass die Diskussionen zu den unterschiedlichen Formen der Obsoleszenz aus unterschiedlichen Gründen geführt wurden und nach einigen Jahren immer wieder abebbten. Auch ist zu beobachten, dass die Diskussion um Obsoleszenz und hier besonders um *werkstoffliche und funktionale Obsoleszenz* seit rund fünf Jahren wieder zunimmt. Dies betrifft vor allem die Diskussion rund um den Begriff der *„geplanten Obsoleszenz"*. Über eine klare Definition der geplanten Obsoleszenz sowie deren Zielsetzung wird sehr kontrovers debattiert. In der populären Medienberichterstattung wird geplante Obsoleszenz als eine absichtliche Lebensdauerverkürzung der Produkte durch den bewussten Einbau von Schwachstellen durch die Hersteller dargestellt. Dabei wird von einer einzigen Zielsetzung ausgegangen, nämlich eine Produktentwicklung, die darauf ausgelegt ist, Verbraucherinnen und Verbraucher zum Zweck der Absatzsteigerung vorzeitig zu einem Neukauf zu zwingen, obwohl das Produkt noch länger nutzbar wäre. Diesem Verständnis von geplanter Obsoleszenz liegt also zu Grunde, dass das Produkt insgesamt – abgesehen von der einen Schwachstelle, die zum Ausfall geführt hat – noch nicht am Ende seiner technischen Lebensdauer angekommen ist.

Zu Beginn waren vor allem Medienberichte in Deutschland, Österreich und der Schweiz zu verzeichnen, in den vergangen zwei Jahren aber auch in anderen europäischen Ländern, von EU-Organisationen[6] und ebenso weltweit. Zahlreiche Medien (Fernsehdokumentationen, ausführliche Reportagen in großen Tages- und Wochenzeitungen) greifen das Thema seitdem regelmäßig auf. In Frankreich enthält die von der Nationalversammlung am 22.07.2015 verabschiedete Fassung des Energiewendegesetztes Maßnahmen gegen geplante Obsoleszenz. Dabei ist vorgesehen, eine Legaldefinition zur geplanten Obsoleszenz einzuführen[7] sowie diese als Betrugstatbestand mit bis zu zwei Jahren Haft und einer Geldbuße bis zu 300.000 Euro oder 5%

[6] Beispielsweise "Stellungnahme des Europäischen Wirtschafts- und Sozialausschusses zum Thema „Für einen nachhaltigeren Konsum: die Lebensdauer von Industrieprodukten und die Verbraucherinformation zugunsten eines neuen Vertrauens" (Initiativstellungnahme), (2014/C 67/05); Verfügbar unter: http://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52013IE1904&from=DE, Zugriff: 10.12.2015

[7] Artikel L 213-4-1 des "Codes de la Consommation" definiert geplante Obsoleszenz als "*Programmed obsolescence is defined by each manoeuvre through which the lifetime of a good is knowingly reduced since its design stage, thereby limiting its usage time for business model reasons*" (Assemblée Nationale 2015).

des Jahresumsatzes eines Unternehmens zu sanktionieren. Darüber hinaus ist vorgesehen, die freiwillige Information der Hersteller zur Lebensdauer eines Produktes einzuführen[8].

Auf der anderen Seite besteht in der Wissenschaft kein Dissens darüber, dass die Produktlebensdauer in der Regel eine planbare Größe ist, an der sich die Produktentwickler orientieren. Die technische Auslegung von Produkten auf eine – unter ökologischen und ökonomischen Aspekten – sinnvolle Lebensdauer kann also ebenfalls als geplante Obsoleszenz bezeichnet werden, folgt aber einem anderen Verständnis als der populäre Mediendiskurs zu diesem Thema.

Darüber hinaus ist die *„psychologische Obsoleszenz“* tendenziell genauso relevant. Hier wird vermutet, dass die Konsumentinnen und Konsumenten Neuheiten gegenüber eher offen sind, innovative Unternehmen honorieren und Neuprodukte kaufen, die sich durch Verbesserung von Funktion und Nutzen gegenüber ihren Vorgängermodellen absetzen. Bei realem Bedarf für eine Neuanschaffung ist eine Orientierung an Innovationen begrüßenswert. Allerdings tendieren Konsumentinnen und Konsumenten auch dazu, Neukäufe zu tätigen, obwohl vorhandene Produkte noch funktionsfähig sind, womit hohe Ressourcenverbräuche ausgelöst werden.

Die Frage der Reparierfreundlichkeit von Produkten ist unter dem Stichwort *„ökonomische Obsoleszenz“* zu diskutieren. Hierzu gehört nicht nur die technische Möglichkeit der Reparatur (Reparierbarkeit), sondern auch die Verfügbarkeit der Reparaturdienstleistung und vor allem deren Kosten. Die Abwägung der Kosten zwischen Ersatzkauf und Reparatur ist häufig ausschlaggebend dafür, ob eine Reparatur erfolgt. Auch darin liegen Gründe für Änderungen bei Nutzungsdauern.

Die Berichterstattung in den Medien zum Thema Obsoleszenz ist von einer sehr anekdotischen Herangehensweise geprägt. Im Allgemeinen ist die Datengrundlage zum Thema Obsoleszenz (werkstofflich, funktional, psychologisch und ökonomisch) lückenhaft, und es fehlt an wissenschaftlichen Ausarbeitungen zu diesem Themenkomplex. Die vorliegende Studie setzt an dieser Stelle an und verfolgt das Ziel, die oben beschriebenen Arten von Obsoleszenz anhand konkreter Produktbeispiele wissenschaftlich aufzuarbeiten und so eine verbesserte Datengrundlage zur Bewertung der Erscheinung „Obsoleszenz“ in Bezug auf Elektro- und Elektronikprodukte zu schaffen.

Zielsetzung

Das übergeordnete Ziel des Vorhabens besteht darin, eine fundierte Datengrundlage zur Beschreibung und Beurteilung der Erscheinung Obsoleszenz bzw. der Trends der erreichten Produktlebens- und Nutzungsdauer zu schaffen und darauf aufbauend handlungssichere Strategien gegen Obsoleszenz bzw. zur Erreichung einer verlässlichen Mindestlebensdauer zu entwickeln. Der Fokus dieses Vorhabens liegt bei Elektro- und Elektronikgeräten für den Einsatz in privaten Haushalten.

Im Konkreten werden hierbei folgende Ziele verfolgt:

1. Erhebung statistischer Daten und Analyse von Trends der Lebens- und Nutzungsdauer von Elektro- und Elektronikgeräten;
2. Systematische Darstellung der Ursachen für die Obsoleszenz bei Elektro- und Elektronikgeräten;

[8] Assemblée Nationale (2015): TEXTE ADOPTÉ n° 575, Projet de Loi - relatif à la transition énergétique pour la croissance verte, Article 99, http://www.assemblee-nationale.fr/14/ta/ta0575.asp; Zugriff: 24.11.2015

Die Anforderungen des Gesetzentwurfs sind unter dem Vorbehalt der Prüfung durch den Verwaltungsrat noch nicht verbindlich.

3. Durchführung von Fallstudien für drei Produktgruppen, um die Datenerhebung zu vertiefen und Maßnahmen zur Erreichung einer möglichst langen oder verlässlichen Lebensdauer für diese ausgewählten Produktgruppen zu identifizieren;
4. Vergleichende Ökobilanz und Lebenszykluskosten zwischen jeweils einem kurz- und langlebigen Produkt für die drei Produktgruppen;
5. Identifizierung von übergreifenden Strategien und Instrumenten gegen Obsoleszenz und zur Lebens- sowie Nutzungsdauerverlängerung bzw. zur Erreichung einer verlässlichen Mindestlebensdauer.

Im Rahmen der Studie werden folgende Produktgruppen behandelt:

- Haushaltsgroßgeräte
  - Kühlschränke
  - Gefriergeräte
  - Waschmaschinen
  - Wäschetrockner
  - Geschirrspüler
  - Elektroherde
- Haushaltskleingeräte[9]
  - Hand- und Stabmixer
  - Wasserkocher
- Informations- und Kommunikationstechnik
  - Desktop-PCs
  - Notebooks
  - Drucker
  - Mobiltelefone/Smartphones
- Unterhaltungselektronik
  - Fernsehgeräte

[9] Kapitel 5 enthält nur Daten für Hand- und Stabmixer. Wasserkocher werden zusätzlich im Rahmen der Ursachenforschung behandelt (Abschnitt **Fehler! Verweisquelle konnte nicht gefunden werden.**). Außerdem werden im Kapitel **Fehler! Verweisquelle konnte nicht gefunden werden.** die Tests der Stiftung Warentest ausgewertet, um die häufigen Defektursachen für elektrische Zahnbürste, Espressomaschinen, Dampfbügeleisen und Staubsauger darzustellen.

Ergebnisse allgemeiner Methoden zur Abschätzung von Lebens-, Nutzungs- und Verweildauer

Replizierbare Tests auf wissenschaftlicher Grundlage, wie sie von der Stiftung Warentest durchgeführt werden, sowie die zahlreichen subjektiven Erfahrungen von Konsumenten und Konsumentinnen (z.B. im Internet-Portal „Murks? Nein Danke!") geben wichtige Hinweise für Qualitätsunterschiede bei Produkten, wiederholt auftretende Qualitätsmängel und Schwachstellen, die zur Einschränkung der Lebensdauer von Produkten führen. Grundsätzliche bzw. repräsentative Aussagen zur Lebensdauer von Elektro- und Elektronikgeräten lassen sich auf Basis der vorliegenden Aussagen allerdings nur beschränkt wissenschaftlich fundiert ableiten.

In der Abfallwirtschaft sind Angaben der Lebensdauern für die Bestimmung künftiger Abfallmengen zentral. Diese Methoden zur Datenbeschaffung stehen allerdings im Spannungsfeld zwischen der Genauigkeit ihrer Ergebnisse und dem dafür betriebenen Aufwand. Die Auswertung wissenschaftlicher Studien über die Ermittlung von Lebensdauern in der Abfallwirtschaft hat zum Beispiel für die Niederlande gezeigt, dass die Lebens- und Nutzungsdauern aller untersuchten Produktgruppen im Vergleich zum Jahr 2000 zurückgegangen sind. Allerdings lassen diese Daten keine Aussage darüber zu, ob dieser Rückgang eher einer kürzeren Nutzungszeit durch die Verbraucherinnen und Verbraucher zuzuschreiben ist oder kürzeren technischen Lebensdauern.

Ergebnisse produktspezifischer Ansätze zur Abschätzung von Lebens-, Nutzungs- und Verweildauer

Die Auswertungen von Daten der Gesellschaft für Konsumforschung (GfK) in dieser Studie zeigen, dass die durchschnittliche Erst-Nutzungsdauer (d.h. die Zeitspanne der Nutzung nur durch den Erstnutzer, nicht zu verwechseln mit technischer Lebensdauer) der Haushaltsgroßgeräte in Deutschland zwischen 2004 und 2012/2013 von 14,1 auf 13,0 Jahre leicht zurückgegangen ist. Die durchschnittliche Erst-Nutzungsdauer der Geräte, die aufgrund eines Defektes ausgetauscht wurden, nahm von 2004 bis 2012/2013 um ein Jahr ab und liegt bei 12,5 Jahren. Über alle Haushaltsgroßgeräte ist der Ersatzkauf aufgrund eines Defektes zwischen 2004 und 2012 insgesamt zwar leicht zurückgegangen, ein Defekt ist jedoch noch immer die Hauptursache des Austauschs. So lag der Anteil der Haushaltsgroßgeräte, die aufgrund eines Defektes ausgetauscht wurden, bei 57,6% in 2004 und bei 55,6% in 2012, bezogen auf die Gesamtersatzkäufe. Auf der anderen Seite lässt sich auch feststellen, dass fast ein Drittel der heute ausgetauschten Haushaltsgroßgeräte noch funktionieren. In 2012/2013 lag der Anteil der Geräte, die aufgrund eines Wunsches nach einem besseren Gerät ausgetauscht wurden, obwohl das alte Gerät noch funktioniert hat, bei 30,5% der Gesamtersatzkäufe. Kritisch zu sehen ist, dass zwischen 2004 und 2012 der Anteil der Haushaltsgroßgeräte, die innerhalb von weniger als 5 Jahren aufgrund eines Defektes ausgetauscht wurden, von 3,5% auf 8,3% der Gesamtersatzkäufe stieg.

Den Trend, dass mehr Haushaltsgroßgeräte innerhalb der ersten 5 Jahre ersetzt werden, bestätigte auch die Analyse der entsorgten Waschmaschinen an den kommunalen Sammelstellen und Recyclinganlagen in 2004 und 2013. Anhand der Analyse des Produktionsdatums des eingebauten Kondensators wurde dabei festgestellt, dass das durchschnittliche Alter der entsorgten Waschmaschinen in 2013 13,7 Jahre betrug. Damit war das durchschnittliche Alter deutlich kürzer als in 2004, wo es bei 16 Jahren lag. Der Altersvergleich zeigte auch, dass 2013 mehr Waschmaschinen mit 11 und weniger Jahren Verweildauer gefunden wurden. Besonders auffällig war, dass mehr als 10% der Waschmaschinen im Jahr 2013 nur 5 Jahre und weniger alt wurden (6% in 2004). Bei Waschmaschinen zeigte ein weiterer Vergleich der gesammelten

Daten auf Markenebene, dass praktisch über alle Marken hinweg eine Verringerung der Verweildauer zwischen 2004 und 2013 festzustellen ist. Bei diesen Daten ist zu berücksichtigen, dass der Ersatzgrund nicht bekannt ist.

Eine weitere internetbasierte Verbraucherbefragung der Universität Bonn in 2013/2014 zeigte außerdem, dass die Waschmaschinen, die durch die an der Befragung teilnehmenden Personen entsorgt wurden, im Mittel 11,6 Jahre alt waren. Dabei wurden 50% der entsorgten Waschmaschinen bis zu 10 Jahren alt. Der Grund für das Ausrangieren der Waschmaschine war in 69 Prozent der Fälle ein Defekt. In 10 Prozent der Fälle war die Waschmaschine nicht sparsam genug.

Im Bereich der *Haushaltskleingeräte* zeigt die Analyse der erhobenen GfK-Daten, dass sich die durchschnittliche Erst-Nutzungsdauer von elektrischen Stab- und Handmixern über die Jahre kaum verändert hat. Diese beträgt in Summe für beide Gerätetypen im Jahre 2012 10,6 Jahre. Betrachtet man die Entwicklung der Erst-Nutzungsdauer beider Gerätetypen getrennt voneinander, so fällt auf, dass elektrische Handmixer einen leichten Rückgang in ihrer Erst-Nutzungsdauer aufzeigen, von anfänglich 12,1 Jahre auf 11,0 Jahre (2012). Sie näherten sich somit der Erst-Nutzungsdauer von Stabmixern an. Diese zeigten über die Jahre, unabhängig vom Hauptkaufgrund, eine durchschnittliche Erst-Nutzungsdauer von 10 Jahren.

Die internetbasierte Verbraucherbefragung der Universität Bonn von 2013/2014 bestätigte mehr oder weniger die oben beschriebene Analyse der Handmixer. Die Ergebnisse der Online-Verbraucherbefragung zeigten, dass die Verbraucherinnen und Verbraucher die entsorgten Handmixer im Mittel 10 Jahre nutzten. Dabei wurden 50% der entsorgten Handmixer bis zu 8 Jahre alt. In den meisten Fällen (76,2%) wurden Handmixer entsorgt, weil sie nach Angabe der Befragten defekt waren. Interessant ist an dieser Stelle der Vergleich mit einer weiteren Erhebung in 2014, in der Handmixer auf der kommunalen Sammelstelle entnommen und nach Entsorgungsgrund untersucht wurden. Bei dieser Untersuchung war bei 9% der Handmixer der mutmaßliche Entsorgungsgrund ein Defekt am Gehäuse, während bei 35% der Geräte ein technischer Defekt den Grund für die Entsorgung darstellte. Bei 52% der Geräte war der Grund für die Entsorgung nicht ersichtlich, da keinerlei Mängel in Bezug auf die Technik, die Mechanik oder das Design festgestellt werden konnten. Insofern zeigen die beiden Erhebungen ein unterschiedliches Bild bezüglich des Entsorgungsgrundes der Handmixer.

Die entsorgten Wasserkocher wurden nach der Online-Verbraucherbefragung der Universität Bonn im Mittel nur 5,7 Jahre alt. Hier erreichte die Hälfte der entsorgten Wasserkocher das Alter von nur 5 Jahren. 68 Prozent der Wasserkocher wurden nach Angabe der Befragten aufgrund eines Defektes entsorgt. Interessant ist auch hier der Vergleich mit der Untersuchung der an der Sammelstelle entnommenen Wasserkocher in 2014. Demnach wiesen 17,9% der Geräte einen mechanischen Defekt am Gehäuse als mutmaßlichen Entsorgungsgrund auf. Bei 28,6% der Geräte war ein technischer Defekt, der Funktionseinbußen mit sich bringt, der mutmaßliche Entsorgungsgrund. Auch hier unterscheiden sich die Ergebnisse der Online-Verbraucherbefragung von denen der Untersuchung an kommunalen Sammelstellen.

Im Bereich der *Unterhaltungselektronik* weisen TV-Flachbildschirme nach der Auswertung der GfK-Daten im Jahr 2007 eine durchschnittliche Erstnutzungsdauer von 5,7 Jahren auf, dieser Wert geht in den Jahren bis 2010 auf 4,4 Jahre zurück. In den Folgejahren (bis 2012) steigt die durchschnittliche Erst-Nutzungsdauer der TV-Flachbildschirme wieder kontinuierlich auf 5,6 Jahre an. Es wird festgestellt, dass die durchschnittlichen Erst-Nutzungsdauern der ersetzten Flachbildschirmfernseher deutlich niedriger sind als die der zur gleichen Zeit ersetzten Röhrenfernseher. Allerdings zeigen die Ergebnisse, dass 2012 über 60% der noch funktionierenden Flachbildschirmfernseher ersetzt wurden, weil die Konsumentinnen und Konsumenten ein besseres Gerät haben wollten. Die durchschnittliche Erst-Nutzungsdauer der Flachbildschirme, die aufgrund eines Defektes ersetzt wurden, lag im Jahr 2009 bei 5,2 Jahre, fiel auf 4,6 Jahre in 2010 und stieg auf 5,2 bzw. 5,9 Jahre in 2011 und 2012. Es lässt sich feststellen, dass der Anteil der defekten Flachbildschirmfernseher an Ersatzkäufen zwischen 2008 und 2012 von 28% auf 25% leicht zurückgegangen ist.

Die Ergebnisse der internetbasierten Verbraucherbefragung der Universität Bonn in 2013/2014 zeigten dagegen, dass die entsorgten Fernseher im Durchschnitt 10 Jahre genutzt wurden. Allerdings ist das Ergebnis darauf zurückzuführen, dass in der Online-Verbraucherbefragung keine Unterscheidung zwischen Röhrenfernsehern und Flachbildschirmen erfolgte. Daher kann davon ausgegangen werden, dass die Röhrenfernseher einen relevanten Anteil an den Aussagen der Internetbefragung ausmachten. Weiterhin zeigen die Ergebnisse, dass 50% der entsorgten Fernsehgeräte nicht älter als10 Jahre waren. 44 Prozent der Fernseher wurden nach Angabe der Befragten wegen eines Defekts ausrangiert. Das heißt, dass umgekehrt 56% der TV-Geräte entsorgt wurden, obwohl diese möglicherweise noch intakt waren.

Im Bereich der *Informations- und Kommunikationstechnik* lässt sich nach der Auswertung der GfK-Daten am Beispiel des Notebooks feststellen, dass die durchschnittliche Erst-Nutzungsdauer in Deutschland zwischen 2004 und 2007 zunächst leicht von 5,4 Jahren (2004) auf 6 Jahre angestiegen (2005/2006) und im Jahr 2007 wieder leicht auf 5,7 Jahre gesunken ist. In 2012 sank die durchschnittliche Erst-Nutzungsdauer von Notebooks noch weiter auf 5,1 Jahre. Die durchschnittliche Erst-Nutzungsdauer der Notebooks, die aufgrund eines Defektes ersetzt wurden, stieg in 2004-2006 von 4,8 auf 6,5 Jahre an und fiel in 2007 wieder auf 5,3 Jahre zurück. In den Jahren 2010-2012 lag die durchschnittliche Erst-Nutzungsdauer zwischen 5,7 und 5,4 Jahren. Ein eindeutiger Trend, etwa dass Notebooks im Zeitverlauf signifikant früher kaputt gehen, ist aus den Daten nicht ableitbar. Der Anteil der defekten Notebooks an allen Ersatzkäufen machte in 2012/2013 über 25% aus. Diejenigen Notebooks, die ersetzt wurden, weil sie fehlerhaft oder unzuverlässig waren, wurden in 2004 durchschnittlich nach 4,8 Jahren ersetzt. Im Zeitraum bis 2012 stieg die durchschnittliche Nutzungsdauer dieser Geräte auf 6,0 Jahre in 2011 und auf 6,2 Jahre in 2012. Dieser Trend deutet auf eine sinkende Fehleranfälligkeit der betrachteten Notebooks im Zeitverlauf zwischen 2004 und 2012 hin. Die durchschnittliche Nutzungsdauer der noch funktionierenden Notebooks, die aufgrund des Wunsches nach einem besseren Gerät ersetzt wurden, beträgt zwischen 2004 und 2012 ca. 6 Jahre. Ein eindeutiger Trend hinsichtlich einer Verlängerung oder Verkürzung der durchschnittlichen Nutzungsdauer kann aus den Daten nicht abgeleitet werden. Es kann allerdings festgehalten werden, dass die Notebooks zwischen 2004 und 2012/2013 immer seltener aufgrund des Wunsches nach einem besseren Gerät ersetzt wurden.

Die Online-Verbraucherbefragung von 2013/ 2014 ergab, dass die entsorgten Notebooks im Mittel nur 4,9 Jahre alt wurden. 50 Prozent der Notebooks in der Umfrage wurden bis zu 5 Jahren alt. In 46 Prozent der Fälle wurde das alte Notebook ausrangiert, da es defekt war. 25 Prozent der Notebooks wurden ersetzt, weil sie zu wenige Funktionen hatten.

Systematisierung der Ursachen für Obsoleszenz

Aufbauend auf der Analyse der Lebens- und Nutzungsdauer von Elektro- und Elektronikgeräten wurden die Ursachen für Obsoleszenz nach vier Kategorien bewertet und systematisiert: (1) Werkstoffliche Obsoleszenz, (2) Funktionale Obsoleszenz, (3) Psychologische Obsoleszenz, und (4) Ökonomische Obsoleszenz (siehe Kapitel **Fehler! Verweisquelle konnte nicht gefunden werden.** für die Definition). Dabei wurden typisch auftretende Faktoren, Merkmale und Komponenten identifiziert, welche zum Ende der jeweiligen Nutzungen führen. Insbesondere für lebensdauerbegrenzende Faktoren, die im Kontext der werkstofflichen Obsoleszenz stehen, wurde untersucht, ob das Ende der Lebensdauer auf bestimmte Verschleißteile zurückzuführen ist. Im Bereich der funktionalen Obsoleszenz stand die Analyse des Einflusses von softwarebedingten Faktoren, wie zum Beispiel Aktualisierung des Betriebssystems und der Treiber sowie Veränderungen in der Standardisierungslandschaft und der medienpolitischen Umgebung (z.B. neue Formate, neue Funktionen, neue Übertragungsstandards usw.) im Mittelpunkt. Im Zusammenhang mit Reparaturmaßnahmen wurde bei allen betrachteten Gerätegruppen die ökonomische Obsoleszenz, also der Vergleich der Kosten für die Reparaturen im Gegensatz zu den Kaufpreisen der neuen Alternativen, näher untersucht. Eine ausführliche Beschreibung der psychologischen Obsoleszenz erfolgte bei denjenigen Produktgruppen, die in der vorangegangenen Lebens- und Nutzungsdaueranalyse als Produktbeispiele für diese Art der Obsoleszenz auffielen (z.B. Fernsehgeräte und Smartphones). Zur Analyse und Systematisierung von Obsoleszenzursachen wurde eine umfassende Auswertung von wissenschaftlichen Studien sowie von unabhängigen Produkttests durchgeführt. Außerdem erfolgte eine Befragung von zahlreichen Expertinnen und Experten, bestehend aus Geräteherstellern, Testinstituten, Reparatur- und Re-Use-Betrieben, akademischen Einrichtungen aus den Bereichen Werkstoffwissenschaften und Design, Normungs- und Standardisierungseinrichtungen sowie Verbraucherorganisationen.

Die Analyse der Obsoleszenzursachen hat gezeigt, dass die untersuchten Geräte aus vielfältigen Gründen ersetzt werden. Dabei wirken werkstoffliche, funktionale, psychologische und ökonomische Obsoleszenzformen zusammen und erzeugen ein hochkomplexes Muster. Selbst die Ursachen der werkstofflichen Obsoleszenz sind in der Regel sehr divers und ermöglichen somit keine eindeutige Schwerpunktsetzung. In der Regel wurde beobachtet, dass praktisch alle Komponenten und Bauteile eines Gerätes ausfallen können. Allerdings haben manche Komponenten und Bauteile vergleichsweise höhere Ausfallwahrscheinlichkeiten und wirken eher lebensdauerlimitierend.

Bei *Fernsehgeräten* zeigt die Analyse, dass die Display-/Bildschirmeinheit, Netzteilkarte, Aluminium-Elektrolytkondensatoren sowie auftretende Transportschäden bei empfindlichen Bauteilen als Hauptursachen für werkstoffliche Obsoleszenz auftraten. Auf der anderen Seite wird festgestellt, dass viele weitere Komponenten, wie zum Beispiel die Hauptplatine, ebenfalls ausfallen können, allerdings mit einer vergleichsweise geringeren Wahrscheinlichkeit. Die werkstoffliche Obsoleszenz stellt nach Aussagen der befragten Expertinnen und Experten nicht das Hauptproblem bei TV-Geräten dar. Die Hauptursache des Ausfalls der Fernsehgeräte liegt bei softwarebedingten Fehlern, also bei der funktionalen Obsoleszenz. Aber der wichtigste Grund, einen älteren Fernseher durch einen neuen zu ersetzen, liegt in der psychologischen Obsoleszenz. In dieser Studie wurde gezeigt, dass in 2012 über 60% der noch funktionierenden Flachbildschirmfernseher ersetzt wurden, weil die Konsumentinnen und Konsumenten ein besseres Gerät haben wollten. Dabei sind das Bedürfnis nach größeren Bildschirmdiagonalen und besserer Bildqualität sowie die fallenden Preise die Hauptfaktoren für den Austausch eines TV-Geräts. Ein Defekt ist zwar ein wichtiger Grund, jedoch selten ausschlaggebend für den Austausch von TV-Geräten.

Bei funktionaler Obsoleszenz spielen die schnelle Weiterentwicklung der TV-Formate in Bezug auf die Auflösung, neue Funktionen und fehlende Vereinheitlichung von Übertragungsstandards eine bedeutende Rolle. Die Entwicklung der neuen TV-Formate hat in den vergangenen Jahren dazu geführt, dass in älteren Geräten die Hardware-Chips (Transmitter- und Receiver-Chips) fehlen, die in der Lage sind, die entsprechenden neuen Formate auszulesen oder die Sendeinhalte in erwünschter Qualität wiederzugeben. Neue Funktionen (z.B. die Verschmelzung von Fernsehen und Internet als Hybrid-TV (HbbTV)), stellen außerdem deutlich höhere Anforderungen an die Software. Wenn die genutzte Software keinen modularen Aufbau hat und ein skalierbarer Speicher in den Geräten fehlt, kommen ältere Geräte aufgrund der neuen Inhalte und Funktionen schnell an ihre Grenzen. Nicht zu unterschätzen ist das steigende „Sourcegut" (d.h. die Quantität an zugrunde liegendem Quelltext), das aufgrund der Einführung von SMART-TVs in den vergangenen Jahren von ca. 1 MB auf über 100 MB angewachsen ist. Um den kompletten Quelltext auf Fehler hin zu testen, also einen sogenannten „Volltest" durchzuführen, benötigt man etwa 15 Arbeitswochen. Da die Produktinnovationszyklen in der Branche sehr kurz sind (Zykluszeit 1 Jahr), wird in vielen Fällen jedoch nicht der komplette Quelltext getestet, sondern häufig nur die typischen Fehlermöglichkeiten geprüft und anhand statistischer Verfahren („Regression") daraus insgesamt Ausfallwahrscheinlichkeiten abgeleitet. Einige Hersteller senken die Testdauern so auf etwa 3 Wochen. Problematisch ist hier jedoch, dass nicht die gesamte Software auf Funktionalität getestet wird, so dass es zu Softwarefehlern kommen kann.

Einer der Gründe, dass die Erst-Nutzungsdauer der defekten oder das Alter der vielen entsorgten Fernsehgeräte auf einem relativ geringen Niveau liegt, liegt sicherlich in der ökonomischen Obsoleszenz. Bei den häufig ausfallenden Komponenten wie der Display- bzw. Bildschirmeinheit und Netzteilkarte entstehen Reparaturkosten von mehreren Hundert Euro. In Relation zu den insgesamt sinkenden Verkaufspreisen von TV-Geräten führt dies möglicherweise dazu, dass Verbraucherinnen und Verbraucher bei einem Defekt das TV-Gerät nicht mehr reparieren lassen, sondern sich stattdessen ein neues Gerät anschaffen.

Für *Smartphones/Mobiltelefone* erfolgte eine Auswertung der online-Reparaturplattform von iFixit (www.ifixit.com). Bei untersuchten Smartphone-Modellen stellten Akku, Bildschirmeinheit, Home Button (zurück zum Startbildschirm) und An-/Ausschalter häufige Reparaturursachen dar. Auch hier wurde beobachtet, dass viele weitere Komponenten ebenfalls ausfallen können.

Die häufige Notwendigkeit für eine Reparatur bzw. den Austausch der Akkus in Smartphones ist möglicherweise auf die steigende Nutzungsintensität sowie steigende Funktionsvielfalt von diesen Geräten zurückzuführen. Davon ausgehend, dass die Austauschbarkeit bzw. Wechselbarkeit von Akkus entscheidend für eine längere Nutzung eines Smartphones sein könnte, wurden die Akku-Demontageanalysen der iFixit-Plattform analysiert. Dies zeigte, dass die Entnahme von Akkus in Modellen ohne fest verbauten Akku in weniger als einer Minute möglich war. Bei zwei Modellen mit fest verbauten Akkus waren allerdings 15–20 Minuten sowie eine Reihe von Spezialwerkzeugen für die Akkuentnahme notwendig. Die Untersuchungen der Stiftung Warentest zeigen, dass der Anteil von Handys mit fest eingebauten Akkus zwischen 2010 und 2013 kontinuierlich gewachsen ist. So besaßen 2013 fast 36% der von Stiftung Warentest untersuchten Handys einen fest eingebauten Akku. In einem weiteren Test in 2014 hat die Stiftung Warentest weitere Smartphones getestet, wovon ca. 35% der Modelle mit einem nicht wechselbaren Akku versehen waren. In solchen Tests befanden sich mehrere Modelle, die bezüglich der Akkuleistung schlechtere Qualitätsurteile bekamen. Die Tatsachen, dass einige Akkus vom Nutzer nicht wechselbar sind in Kombination mit unzureichender Akkuleistung, lassen vermuten, dass diese Modelle im Laufe der Nutzung aufgrund von schwacher Akkuleistung ersetzt werden.

Eine weitere Untersuchung der Stiftung Warentest zeigt allerdings, dass nur 9% der Befragten, die innerhalb von 3 Jahren ihr Handy wechselten, einen Akkudefekt oder schwache Akkuleistung als Ersatzursache genannt haben. 68% der Befragten gaben dagegen an, das Handy innerhalb von 3 Jahren zu wechseln, entweder weil sie einfach ein noch besseres Gerät haben wollten (40%) oder sie durch den Vertrag regelmäßig ein neues Gerät bekommen (28%), d.h. eine psychologische Obsoleszenz. Weiterhin zeigen andere Befragungen der Stiftung Warentest, dass 42% der Nutzer in Deutschland ihr Mobiltelefon innerhalb von zwei Jahren austauschen. Etwa

16% der Nutzer tauschen das Mobiltelefon alle drei Jahre aus. Zusammenfassend kann festgehalten werden, dass die psychologische Obsoleszenz die entscheidende Rolle bei der Begrenzung der Nutzungsdauer von Smartphones/Mobiletelefonen spielt.

Bei *Notebooks* zeigen die Analysen der werkstofflichen Obsoleszenz, dass bei Geräten für Privathaushalte (Consumer-Notebooks) Festplattenlaufwerke, Arbeitsspeicher, Grafikchips und Akkus (jeweils sehr häufig) sowie Hauptplatine, Prozessorlüfter, Netzteile, periphere Schnittstellen, Bildschirm und -abdeckungen (Scharniere) und Notebookgehäuse (jeweils häufig) ausfallen können. Auffällig ist, dass sich gewerblich eingesetzte Geräte (Business-Notebooks) bei den Ausfallwahrscheinlichkeiten der Komponenten von Consumer-Notebooks unterscheiden. Bei Business-Notebooks fallen Festplattenlaufwerke und Akkus häufig aus, alle weiteren Komponenten dagegen nur selten. Hauptgründe für die Ausfallwahrscheinlichkeiten sind thermische Probleme, mechanische Abnutzung und fahrlässiger Umgang. Weiterhin sind festverbaute Akkus, eingelötete Arbeitsspeicherelemente und festverbaute Festplatten als lebensdauerlimitierende Faktoren zu verstehen. Außerdem hängt die Lebensdauer der verbauten elektrischen und elektronischen Bauteile (z.B. Aluminium-Elektrolytkondensatoren) und Bauteilgruppen entscheidend von der Dimensionierung der Komponenten und ihrer thermischen Exposition ab.

In der Online-Verbraucherbefragung gaben die teilnehmenden Personen für den Anteil defekter Notebooks an, dass in ca. einem Drittel der Fälle der Akku der Grund für den Ausfall war, gefolgt von Hauptplatine (ca. 23%), Bildschirm und Lüfter (jeweils ca. 19%) sowie Grafikkarte (13%). Weitere Studien und unabhängige Produkttests zeigen, dass die Scharniere an Gehäusedeckeln sowie andere exponierte oder unterdimensionierte Komponenten-Verbindungen, die hoher Beanspruchung ausgesetzt sind, ein Problem darstellen. Unbeabsichtigte Stöße und Stürze, aber auch die Dauerbeanspruchung (z.B. Festplatte und festverbaute Leiterplatten-Komponenten) führen zu Defekten oder zum Ausfall von Geräten. Eine weitere Untersuchung (SquareTrade 2009) kam zu dem Ergebnis, dass 20,4% der untersuchten Notebooks auf Grund von Hardwarefehlern innerhalb der ersten drei Nutzungsjahre ausgefallen sind und weitere 10,6% der Geräte in dieser Zeit durch Unfälle und unsachgemäßen Gebrauch In einer Studie des britischen Forschungsinstituts WRAP zu Notebooks wurde festgestellt, dass 7% der Geräte im ersten Jahr ausfallen, knapp 20% im zweiten Jahr und nach dem dritten Jahr bereits ein Drittel der Geräte ausgefallen sind.

Was die Wechselwirkung zwischen der funktionalen Obsoleszenz und den Hardwaretreibern angeht, sind insbesondere die Hersteller der Peripheriegeräte gefordert, die Treiber für eine längere Zeit zur Verfügung zu stellen, da die Support- und Entwicklungszyklen der Betriebssysteme sowie ein Wechsel der Treiberarchitektur langfristig angekündigt werden. Die funktionale Obsoleszenz, die durch eine Aktualisierung des Betriebssystems hervorgerufen wird, hat in der Vergangenheit dazu geführt, dass die älteren PCs die Mindestanforderungen des neuen Betriebssystems nicht einhalten konnten. Außerdem führte die Einstellung des Supports für ältere Betriebssysteme dazu, dass sicherheitsrelevante Betriebssystem- und Software-Updates nicht mehr zur Verfügung standen, um Schutz vor Trojanern und Viren zu bieten. Als Konsequenz musste die Hardware ausgetauscht werden bzw. der PC durch ein neues Gerät ersetzt werden, obwohl die technische Lebensdauer noch nicht ausgeschöpft war. Auch mit der Einstellung des Windows XP ging der Austausch einer großen Zahl älterer, aber noch funktionstüchtiger Desktop-PCs und Notebooks weltweit einher. Allerdings wurde das Betriebssystem schon knapp 13 Jahre lang unterstützt. Die Installation eines aktuellen Windows-Betriebssystems (Windows 7 oder höher) lässt sich ebenfalls bei sehr viel älteren Desktop-PCs und Notebooks nicht mehr umsetzen. Die Rechner, die nur wenige Jahre alt sind, sind allerdings mit dieser Aktualisierung in der Regel weniger betroffen.

Die Analyse legt weiterhin nahe, dass bei Notebooks die psychologische Obsoleszenz inzwischen eine geringere Rolle spielt. Daraus kann geschlossen werden, dass die symbolische Bedeutung von Notebooks als Modeaccessoire oder als Anzeiger für die eigene gesellschaftliche Stellung abgenommen hat. Gleichzeitig kann auch davon ausgegangen werden, dass die Innovations-zyklen verlangsamt und die Entwicklungsarbeit in andere Bereiche (z.B. Tablet-Computer) verlagert wurde.

Fest verklebte Akkus und Spezialschrauben vor Motherboard, Arbeitsspeichern oder Fest-platten, die nur mittels Spezialwerkzeugen geöffnet werden können, lösen u.a. die ökonomische Obsoleszenz aus. Bei Notebooks entstehen für den Austausch von Mainboard, Prozessor und Grafikchip die höchsten Kosten für die Reparatur. In diesen Fällen kann davon ausgegangen werden, dass die Reparaturen oft ausbleiben und eher neue Geräte angeschafft werden. Mit etwas geringerem Kostenaufwand können Arbeitsspeicher, Prozessorkühler, Festplatte, Akkus und bei einigen wenigen der Bildschirm erweitert oder ausgetauscht werden.

Zur Untersuchung der Obsoleszenzursachen für *Waschmaschinen* wurden die Ergebnisse der Lebensdaueruntersuchungen der Stiftung Warentest, die sie in den letzten 15 Jahren durchge-führt hat (Jahre 2000-2014), ausgewertet und die Probleme identifiziert, die die Lebensdauer von Waschmaschinen begrenzt haben. Die Tests umfassten rund 600 Waschmaschinen von 196 verschiedenen Modellen. Von diesen 196 Modellen sind an 41 Modellen Probleme während der Prüfung einer 10-jährigen Benutzung aufgetreten, die zu einer ‚mangelhaften‘ Bewertung der Lebensdauer durch die Stiftung Warentest geführt haben. Die Analyse der Ausfallursachen zeigte dabei kaum wiederkehrende Ausfälle. Praktisch alle Elemente einer Waschmaschine tauchten als Ausfallursache auf. Insbesondere die Bauteile, die einer erhöhten Schwingungsbe-lastung ausgesetzt sind (alle am Bottich befestigten Teile) scheinen allerdings öfter auszufallen als andere Bauteile. Ebenfalls zeigten die Forschungen des britischen Instituts WRAP, dass eine Reihe von Ursachen die Lebensdauer von Waschmaschinen verkürzen könnte. Als Hauptur-sachen wurden Probleme in der Elektronik, Türdichtung und -scharniere, Zulauf- und Abfluss-schlauch, Wasserheizelemente, Trommelbehälter, Motor und Seifenschubfach erwähnt. Die teilnehmenden Personen der Online-Verbraucherbefragung nannten den Defekt der Elektrik (28%), gefolgt von dem Defekt der Pumpe (23%) und einem Lagerschaden (15%) als Haupt-gründe für den Ausfall.

Die im Rahmen der Studie befragten Expertinnen und Experten betonten außerdem die Ausfall-srisiken, die mit der Verkleinerung des Aufbaus von Halbleitern und der rasanten Erhöhung der Integrationsdichte der speicherbaren Information auf Halbleitern einhergehen. Allerdings werden elektronische Bauteile vielfach in Varianten angeboten, die über eine unterschiedliche Ausfallwahrscheinlichkeit in Abhängigkeit von den Einsatzbedingungen (insbesondere der Temperatur) verfügen. Grundsätzlich können auch durch einen erhöhten Testaufwand der Bauteile und integrierten Schaltungen die potenziellen Ausfallursachen erkannt und beseitigt werden, allerdings mit Auswirkungen auf die Kosten. Auf der anderen Seite ist es ebenfalls wichtig zu verstehen, dass der Einsatz von elektronischen Sensoren und Mikroprozessoren zur Steuerung oder Regelung die Verwendung viel kleinerer Abstände und damit eine viel stärkere Integration von Funktionen in einem Halbleiterchip oder auf einer Platine erlaubt. Damit ent-fallen gleichzeitig auch viele Steckkontakte zwischen einzelnen Bauteilen und damit viele Fehlermöglichkeiten. Zudem erlaubt die Integration auf einer Komponente eine sehr viel weitergehende Prüfung der Funktionsfähigkeit dieser Komponente vor ihrem Einbau in ein Gerät.

Die funktionale Obsoleszenz steht bei Waschmaschinen in Zusammenhang mit der Entwicklung und dem Einsatz von Waschmitteln sowie Textilien. Ältere Waschmaschinen können durchaus weiter funktionieren, ihre Fähigkeiten aber, moderne Waschmittel ressourcenschonend zu nutzen und moderne Textilien optimal zu pflegen, sind eingeschränkt. Es konnte gezeigt werden, dass ältere Waschmaschinen viel mehr Energie benötigen, um eine gute Waschwirkung zu erzielen. Tatsächlich mussten alte Maschinen zum Zeitpunkt der Durchführung von Tests in 2004, um die gleiche Waschwirkung wie neue Maschinen in einem 40°C-Programm zu erreichen, im 90°C-Programm betrieben werden. Darüber hinaus war die Waschwirkung bei 40°C von alten Waschmaschinen viel niedriger als die von neueren Waschmaschinen. Die Untersuchungen (Jahr 2004) zeigten, dass eine neue Maschine nur etwa halb so viel Energie wie eine 15-jährige Maschine und ein Viertel der Energie einer 30-jährigen Maschine benötigte, um die gleiche Waschleistung zu erreichen. Ein Vergleich des Wasserverbrauchs bei konstanter Beladung zeigte ähnliche Faktoren für eine Verbesserung im Laufe der Zeit. Auch in Zukunft werden sich die Waschmaschinen, Textilien und Waschmittel weiterentwickeln. Deshalb kann nicht ausgeschlossen werden, dass heute moderne Waschmaschinen in ein oder zwei Jahrzehnten nicht mehr fähig sein werden, mit den dann angebotenen Waschmitteln und Textilien optimal umzugehen. Aus der internetbasierten Verbraucherbefragung kann man in etwa ableiten, dass diese Effekte der funktionalen Obsoleszenz für ca. 12% der Haushalte der Grund für die Anschaffung einer neuen Waschmaschine waren.

Die Analyse der ökonomischen Obsoleszenz bei Waschmaschinen bestätigte nochmal die hohen Reparaturkosten als eine mögliche Hürde. Theoretisch ist eine Reparatur aller ausgefallenen Bauteile und Komponenten einer Waschmaschine möglich, jedoch sind die Kosten teilweise sehr hoch. Dies liegt insbesondere daran, dass diese Reparaturen vor Ort durchgeführt werden und deshalb Anreisekosten für das Servicepersonal anfallen. Zusammen mit Ersatzteilkosten entstehen bei einigen Reparaturen, beispielsweise der Steuerungselektronik, des Motors, des Laugenbehälters oder der Kugellager, Kosten von mehreren Hundert Euros. Dem entgegen steht eine drastische Verringerung der Marktpreise von neuen Waschmaschinen, insbesondere bis zum Jahr 2004.

Auslegung der Produktlebensdauer

In den letzten Jahren hat die Medienberichterstattung das Thema „geplante Obsoleszenz" sehr emotional präsentiert und die Gesellschaft in zwei voneinander unabhängige Pole geteilt, nämlich Hersteller und Industrie als „Täter" und die Verbraucherinnen und Verbraucher als „Opfer" der Obsoleszenz. Die vorliegende Studie hat gezeigt, dass die Erscheinung Obsoleszenz von Produkten nicht so eindimensional ist. Hersteller und Verbraucher interagieren miteinander in einer sich stetig wandelnden Umgebung und beeinflussen gegenseitig die Produktentwicklung und Konsummuster.

In diesem Kontext besteht in der Frage, ob Hersteller die Lebensdauer ihrer Produkte planen, im Grunde kein Dissens. Die Produktlebensdauer ist eine planbare Größe. Die Auslegung der Produktlebensdauer wird von vielen Faktoren beeinflusst, wie zum Beispiel Belastung, Abnutzungsvorrat, Wartung, technologischer Wandel bei Produkten, Mode, Wertewandel und weitere äußere Umwelteinflüsse. Idealerweise wird angestrebt, dass die technische Produktlebensdauer der Produktnutzungsdauer gleich ist. Um ein solches Optimierungsziel zu erreichen sollen alle Bauteile so ausgelegt sein, dass sie ein möglichst ähnliches Zeitintervall an Lebensdauer erreichen, um beispielsweise die Kosten und den Aufwand für unnötige Abnutzungsvorräte zu vermeiden. Das Kernprinzip lautet, Produkte so zu gestalten, dass sie so lang wie nötig und nicht so lang wie möglich halten. Deswegen stehen Anforderungen an Produkte im Kontext der jeweiligen Nutzungsparameter und -umgebung. Das heißt, dass sich die Auslegung der Produktlebensdauer an der Zielsetzung und den Zielgruppen sowie an den zukünftigen Markt- und Technologieentwicklungsszenarien orientiert. Die Anforderungen sind deshalb von Produkt zu Produkt unterschiedlich, was sich auch im Endverkaufspreis ausdrückt. Dieser wird aber auch von anderen Faktoren wie angebotenem Service, Dauer der Verfügbarkeit von Ersatzteilen, Zusatznutzen, Design, Updates, Reparaturfähigkeit, mechanische und elektronische Robustheit bestimmt. Diese Entscheidungsgrundlagen der Unternehmen sind allerdings für die Konsumentinnen und Konsumenten nicht sichtbar. Die fehlende Transparenz bewirkt, dass sie ihre Kaufentscheidung hinsichtlich der eigenen Bedürfnisse nicht optimal treffen können (asymmetrische Information).

Den Sachverhalt der geplanten Obsoleszenz im Sinne einer Designmanipulation oder bewusstem Einbau von Schwachstellen haben die Analysen in der Studie nicht bestätigt, jedoch war dies auch nicht die primäre Zielsetzung der Studie. In der Studie wurden drei typische Fallbeispiele, die in den Medien als Paradebeispiele für eine geplante Obsoleszenz im Sinne einer Designmanipulation angeprangert werden, näher untersucht: (1) Aluminium-Elektrolytkondensator (Elko), (2) Kunststofflaugenbehälter in Waschmaschinen, und (3) Tintenschwämmchenreservoir bei Tintenstrahldruckern. In allen drei Fällen konnte der Vorwurf einer geplanten Obsoleszenz im Sinne einer Designmanipulation nicht aufrechterhalten werden.

Bei *Elkos* wurde festgestellt, dass es sicher kein befriedigendes Ergebnis ist, dass sie als temperaturempfindliche Bauteile in der Nähe von Wärmequellen platziert werden. Allerdings müssen sie aufgrund von technischen und physikalischen Gegebenheiten dort platziert werden, um die Funktionsfähigkeit des Gerätes gewährleisten zu können. Nur bei naher Platzierung am Prozessorsockel kann der elektrische Serienwiderstand gering gehalten und die dynamischen Eigenschaften der Schaltung verbessert werden. Es handelt sich also um eine Designentscheidung, bei der ein ausgewogener Kompromiss im Spannungsfeld unterschiedlich ausgerichteter Wirkungsprinzipien gefunden werden muss. Auf der anderen Seite ist die richtige Dimensionierung von Elkos ohne Frage entscheidend für die Produktlebensdauer. Die Auswahl der Elkos erfolgt nach betriebswirtschaftlichen Prinzipien während eines komplexen Produktentwicklungsprozesses, bei dem die zu erwartende Lebens- und Nutzungsdauer die Grundlage für die Produktgestaltung bildet. Weichen allerdings die realen Betriebsbedingungen von denen ab, die als Grundlage für die Auswahl von Elkos gebildet haben, können die Elkos als lebensdauerlimitierende Komponenten vorzeitig zum Produktausfall führen. Qualitätsdefizite in der Zulieferkette können ebenfalls dazu beitragen. Aus diesen Gründen ist es sinnvoll, dass neben Mindestanforderungen an die Dimensionierung der Elkos und Formulierung von realitätsnahen Betriebsbedingungen für die Funktionsprüfung ein striktes Qualitätsmanagement in der Zuliefererkette umgesetzt wird. Die dabei entstehenden Mehrkosten für den Gerätehersteller scheinen im Hinblick auf den ökologischen Nutzen der Lebensdauerverlängerung nicht signifikant zu sein.

Was der Einsatz von *Kunststofflaugenbehältern* in den Waschmaschinen angeht, bietet der Kunststoff neben den Kostenvorteilen auch eine Reihe von weiteren Vorteilen (z.B. Geräuschverhalten, thermische Verluste, Korrosion) gegenüber Behältern aus Edelstahl. Wichtig ist dabei ausreichendes Knowhow bei der konstruktiven Auslegung von hochbelasteten Kunststoffbauteilen, vor allem hinsichtlich der Strukturmechanik, chemischer Beständigkeit und thermischen Belastungen. Die unabhängigen Untersuchungen der Stiftung Warentest über die Lebensdauer von Waschmaschinen der letzten 15 Jahre an rund 600 Maschinen (= 196 Modelle á drei Geräte pro Test) haben gezeigt, dass es nur an wenigen Geräten zu Problemen gekommen ist, die man einem Kunststoffbottich zuordnen könnte. Dabei ist davon auszugehen, dass rund 90% der getesteten Geräte über einen Kunststoffbottich verfügten. Allerdings hat die Stiftung Warentest bisher nur Geräte in Preisklassen größer als 350 € getestet.

Die Problematik des *Tintenschwämmchenreservoirs* steht im Zusammenhang mit einer Schutzvorrichtung. Die Fehlermeldung bzw. Funktionseinstellung, die nach einer bestimmten Anzahl von Druckseiten erscheint, soll verhindern, dass mögliche Folgeschäden, wie

Verschmutzung durch Auslaufen der Tinte, auftreten, wenn die Kapazität des Tintenschwämmchens erreicht ist. Nichtsdestotrotz zeigt eine kritische Betrachtung der Schutzvorkehrung jedoch, dass der Auslaufschutz technisch auch anders realisiert werden kann, ohne gleich die Funktion des ganzen Geräts stillzulegen. Dabei werden austauschbare Resttintenbehälter eingesetzt, die in Modellen ab der mittleren Preisklasse zum Einsatz kommen. Auch ist zu bemängeln, dass diese begrenzte Kapazität des Tintenschwämmchenreservoirs den Verbraucherinnen und Verbrauchern beim Kauf häufig nicht bekannt ist.

Daraus kann abgeleitet werden, dass je genauer die Hersteller ihre Lebensdauertests durchführen, je genauer sie ihre Testbedingungen an reale Nutzungsbedingungen anpassen und je genauer sie die Qualitätsstandards in der Zulieferkette prüfen, umso sicherer können sie Aussagen über die zu erwartende Lebensdauer machen, also mit welcher Wahrscheinlichkeit eine bestimmte Lebensdauer erreicht wird oder mit welcher Wahrscheinlichkeit bestimmte Bauteile wann ausfallen. Auf der anderen Seite ist zu beobachten, dass vor dem Hintergrund von schnellen Produktzyklen, sinkenden Produktpreisen sowie kosten- und zeitaufwändigen Lebensdauertests die Anwendung von Lebensdauertests in der Praxis stark verkürzt ist, und mitunter nur die wichtigsten Funktionen geprüft werden. Dies führt dazu, dass die Hersteller selber keine absolut richtungssicheren Angaben über die Lebensdauer ihrer Produkte mehr machen können.

Den Vorwurf vollständig zu be- oder widerlegen, dass Hersteller bestimmte Bauteile bewusst so auslegen, dass sie nach einer vorher definierten Zeit aufgrund eines Defektes ausfallen, um Verbraucherinnen und Verbraucher zu Neukäufen zu zwingen, war nicht die Primärzielsetzung dieser Studie. Vielmehr diente die Studie der Analyse der Trends von Lebens- und Nutzungsdauer sowie der Ausfallursachen bzw. Gründe für den Ersatz von Produkten. Die Analyse hat gezeigt, dass es in der Realität sehr vielfältige Gründe gibt, Produkte zu ersetzen. Es wird allerdings auch festgestellt, dass die Geräte heute vermehrt nach kürzeren Nutzungsdauern ersetzt oder entsorgt werden. Aus ökologischen Gesichtspunkten ist diese Praxis nicht akzeptabel.

Ökologische und ökonomische Vergleichsrechnung zwischen kurz- und langlebigen Produkten

In dieser Studie wurden für Waschmaschinen, Fernsehgeräte und Notebooks ökologische und ökonomische Vergleichsrechnungen zwischen kurz- und langlebigen Varianten durchgeführt. Die Ergebnisse der ökologischen Vergleichsrechnung zeigen ein eindeutiges Bild. Bei allen untersuchten Produktgruppen schneiden die langlebigen Produkte in allen Umweltkategorien besser ab als die kurzlebigen Varianten. Das ist der Fall, obwohl neben der Energieeffizienzsteigerung der neuen Geräte und dem höheren Herstellungsaufwand des langlebigen Produktes auch die Nachrüstung/Reparatur des langlebigen Geräts mit Ersatzteilen (inkl. deren Herstellungsaufwand) in die Bilanzierung miteinbezogen wurde.

Bei *Waschmaschinen* sind der kumulierte Energieaufwand (KEA) und das Treibhauspotenzial einer kurzlebigen Waschmaschine (Lebensdauer 5 Jahre) ca. 40% höher im Vergleich zu der langlebigen Waschmaschine (Lebensdauer 20 Jahre). Über einen Betrachtungszeitraum von 20 Jahren verursacht eine langlebige Waschmaschine knapp 1100 kg weniger CO_2e als die kurzlebige Variante Das Versauerungspotenzial einer kurzlebigen Waschmaschine ist ca. 60% höher im Vergleich zu der langlebigen Waschmaschine. Der Unterschied zwischen einer langlebigen Waschmaschine und einer durchschnittlichen Waschmaschine (Lebensdauer 10 Jahre) ist deutlicher geringer; die langlebige Waschmaschine schneidet aber trotzdem in den meisten Umweltkategorien besser ab (z.B. 12% weniger Treibhauspotenzial und 18% weniger Versauerungspotenzial).

Bei *Fernsehgeräten* liegt der Umweltindikator Versauerungspotenzial um 42% höher für ein kurzlebiges Fernsehgerät (Lebensdauer 5,6 Jahre) im Vergleich zu der langlebigen Variante (Lebensdauer 10 Jahre). Der kumulierte Energieaufwand eines kurzlebigen Fernsehgeräts ist 28% höher und das Treibhauspotenzial 25% höher im Vergleich zu einem langlebigen Fernsehgerät. Über einen Betrachtungszeitraum von 10 Jahren verursacht ein langlebiges TV-Gerät knapp 600 kg weniger CO_2e als die kurzlebige Variante.

Bei *Notebooks* verursacht das langlebige Produkt (Lebensdauer 6 Jahre) über einen Betrachtungszeitraum von 12 Jahren knapp 300 kg weniger CO_2e als die kurzlebige Variante. Der Umweltindikator Versauerungspotenzial liegt um 49% höher für ein kurzlebiges Notebook (Lebensdauer 3 Jahre) im Vergleich zu der langlebigen Variante. Der kumulierte Energieaufwand eines kurzlebigen Notebooks ist 25% höher und das Treibhauspotenzial 36% höher im Vergleich zu einem langlebigen Notebook.

Die ökonomischen Vergleichsrechnungen zwischen kurz- und langlebigen Produktvarianten wurden mit dem Ansatz der Lebenszykluskosten durchgeführt. Dabei spielen die getroffenen Annahmen bezüglich der Anschaffungskosten eine entscheidende Rolle und beeinflussen das Ergebnis sehr stark. Die Differenz der Anschaffungskosten zwischen kurzlebigen und langlebigen Produktvarianten ist eine entscheidende Größe, die die Kosteneinsparungseffekte oder die Mehrkosten eines langlebigen Produktes im Vergleich zu einer kurzlebigen Variante bestimmt. Ist die Differenz gering, käme es in der Regel zu größeren positiven Kosteneinsparungseffekten bei langlebigen Produkten. Auf der anderen Seite würde das langlebige Produkte im Hinblick auf die Lebenszykluskosten sogar schlechter abschneiden oder seine positiven Kosteneinsparungen eher geringer ausfallen, wenn seine Anschaffungskosten gegenüber einer kurzlebigen Variante deutlich höher sind. Auch die angesetzten Energieeffizienzsteigerung sowie Reparatur- und Ersatzteilkosten spielen eine wichtige Rolle. Ist die Energieeffizienz der neu angeschafften kurzlebigen Produkte erheblich besser als die Vorläufergenerationen, die Differenz der Anschaffungskosten zwischen kurz- und langlebigen Varianten sowie Reparaturkosten hoch, würden in der Regel negative Kosteneffekte für die langlebigen Produkte zum Vorschein kommen.

Die im Rahmen dieser Studie durchgeführten Berechnungen zeigen, dass die jährlichen Gesamtkosten einer langlebigen *Waschmaschine* mit 20 Jahren Lebensdauer am geringsten sind. Im Vergleich dazu verursacht eine kurzlebige Waschmaschine mit 5 Jahren Lebensdauer ca. 13% Mehrkosten. Verglichen mit einer kurzlebigen Waschmaschine lassen sich mit dem Kauf einer langlebigen Waschmaschine pro Gerät ca. 283 € in 20 Jahren sparen. Eine langlebige Waschmaschine müsste nach den in dieser Studie getroffenen Annahmen einen ca. 270% höheren Kaufpreis als die kurzlebige Variante haben, um die Lebenszykluskosten der kurzlebigen Waschmaschine zu überschreiten.

Beim langlebigen *Fernsehgerät*, das während seiner Lebensdauer von 10 Jahren gar nicht repariert werden muss, sind die jährlichen Gesamtkosten geringer im Vergleich zu der kurzlebigen Variante. Allerdings ist der Unterschied zu der kurzlebigen Variante (Lebensdauer 5,6 Jahre) fast vernachlässigbar. Bemerkenswert ist, dass die jährlichen Gesamtkosten eines kurzlebigen TV-Geräts geringer sind als die eines langlebigen TV-Geräts, das während seiner Lebensdauer repariert werden muss. Die vergleichsweise hohen Kosten bei dem langlebigen TV-Gerät in dieser Beispielrechnung sind neben den hohen Anschaffungskosten auf die hohen Reparaturkosten zurückzuführen. Ein langlebiges TV-Gerät (ohne Reparatur) müsste nach den in dieser

Studie getroffenen Annahmen einen ca. 75% höheren Kaufpreis haben als die kurzlebige Variante, um die Lebenszykluskosten des kurzlebigen TV-Geräts zu überschreiten.

Beim langlebigen *Notebook*, das während seiner Lebensdauer von 6 Jahren gar nicht repariert werden muss, sind die jährlichen Gesamtkosten geringer als die der kurzlebigen Variante. Die jährlichen Gesamtkosten eines langlebigen Notebooks, das mehrfach repariert werden muss, um eine sechsjährige Lebensdauer zu erreichen, liegen aufgrund von hohen Reparaturkosten höher als die eines kurzlebigen Notebooks (Lebensdauer 3 Jahre). Verglichen mit einem kurzlebigen Notebook lassen sich mit dem Kauf eines langlebigen Notebooks, bei dem keine Reparaturen durchgeführt werden müssen, pro Gerät ca. 196 € in 12 Jahren sparen. Bei dem reparaturbedürftigen langlebigen Notebook fallen in 12 Jahren ca. 261 € Mehrkosten an als bei der kurzlebigen Variante. Ein langlebiges Notebook (ohne Reparatur) müsste nach den in dieser Studie getroffenen Annahmen fast einen doppelt so hohen Kaufpreis haben als die kurzlebige Variante, um die Lebenszykluskosten des kurzlebigen Notebooks zu überschreiten.

Strategien gegen Obsoleszenz

Ausgehend von der Ursachenanalyse wurden in dieser Studie Strategien gegen Obsoleszenz von Elektro- und Elektronikgeräten entwickelt. Dabei lag der Fokus auf *technischen und produktspezifischen sowie managementbezogenen Strategien und Lösungsoptionen*. Das Hauptziel war dabei, eine gesicherte Mindestlebensdauer oder Lebens- und Nutzungsdauerverlängerung von Elektro- und Elektronikgeräten zu erreichen. Dafür wurde eine Konsolidierung und Bündelung der Ursachen für Ausfälle und Ersatz in übergeordneten Themenclustern vorgenommen. Damit ließen sich Strategien, unabhängig von der Produktgruppe sowie unabhängig von jedem einzelnen Ersatzgrund, definieren, die das gesamte Themencluster und somit diverse darunterfallende Produktgruppen und Obsoleszenzursachen adressieren. In der folgenden Tabelle sind die Themencluster und die dazugehörigen Ursachen für Ausfälle und Ersatz von Waschmaschinen, Notebooks und Fernsehgeräten abgebildet. Alle Ursachen lassen sich in insgesamt 4 Hauptthemencluster aufteilen. Die identifizierten Ausfall- und Ersatzursachen der Produktgruppen Waschmaschinen, Notebooks und Fernsehgeräte wurden diesen Themenclustern zugeordnet. Durch diese Zuordnung entstand ein guter Überblick, welche Obsoleszenzursachen für alle untersuchten Produktgruppen gleichermaßen gelten und eher mit produktgruppenübergreifenden horizontalen Strategien adressiert werden können, und welche Obsoleszenzursachen eher produktgruppenspezifische Lösungsansätze benötigen.

Tabelle 1 Beschreibung und Zuordnung der Obsoleszenzursachen

Themencluster für die Obsoleszenzursachen		Waschmaschinen	Notebooks	Fernsehgeräte
1	**Mangelnde mechanische und elektronische Robustheit (Werkstoffliche Obsoleszenz)**			
1.1	Vorgabe an die Fertigung für die zu erreichende Lebensdauer nicht vorhanden oder zu kurz. Die fehlende Transparenz bewirkt, dass Konsumentinnen und Konsumenten ihre Kaufentscheidung hinsichtlich der eigenen Bedürfnisse nicht optimal treffen können (asymmetrische Information).	X	X	X
1.2	Komponenten werden in der laufenden Fertigung oder in der Freigabe nicht hinreichend auf die Einhaltung der Lebensdaueranforderungen geprüft.	X	X	X

Themencluster für die Obsoleszenzursachen		Waschmaschinen	Notebooks	Fernsehgeräte
1.3	Belastung ist in der Realität höher als die Lebensdaueranforderungen, die als Maßstab für die Fertigung zugrunde gelegt wurden.	X	X	X
1.4	Das Gesamtgerät wird nicht hinreichend auf die Einhaltung der Lebensdaueranforderung geprüft.	X	X	X
1.5	Verschiedene Produktionsserien gleichartiger Geräte enthalten unterschiedliche Bauteile. Der hohe Wettbewerbsdruck schafft Volatilität in Verfügbarkeit und Qualität der Komponenten. Die Qualitätsstandards der Hersteller, wenn überhaupt vorhanden, lassen sich vertikal nicht bis in Zulieferketten implementieren.	X	X	X
1.6	Schlechtes Gerätedesign und Wärmemanagement, wie z.B. Lüftungsschlitze, die durch Staub- und Schmutzpartikel verstopft werden und zu Überhitzungen im Gerät führen.		X	X
1.7	Kurze Akkulebensdauer (Laufzeit und Kapazität) limitiert Nutzung (elektrochemische Robustheit); fest verbaute Akkus erschweren oder verhindern einen gezielten Austausch.		X	
2	**Softwarebedingte Gründe (Funktionale Obsoleszenz)**			
2.1	Immer neue TV-Formate (z.B. HD Ready, Full HD, UHD), neue Funktionen (z.B. HbbTV) und somit der Anstieg des Sourceguts stellen höhere Anforderungen sowohl an die Software als auch an die Hardware.			X
2.2	Unterschiedliche Übertragungsstandards, fehlende Standardisierung von dynamischer Kanalverwaltung sowie Schnittstellen und Conditional Access Systeme.			X
2.3	Für ältere Komponenten und Peripheriegeräte (z.B. manche Grafikarten, Drucker und Scanner) geben Hersteller für aktuelle Betriebssysteme oft keine aktualisierten Treiber mehr heraus, sodass diese dann nicht mehr bzw. nicht im gewohnten Umfang weitergenutzt werden können.		X	
2.4	Die Installation eines aktuellen Betriebssystems lässt sich bei älteren Notebooks nicht mehr umsetzen, da die Grenze der Leistungsfähigkeit erreicht ist. Können die Mindestanforderungen des Betriebssystems nicht eingehalten werden, ist das Betriebssystem auf dieser Hardware nicht lauffähig und diese muss ausgetauscht werden, obwohl das technische Lebensende noch nicht erreicht ist.		X	

Themencluster für die Obsoleszenzursachen		Waschmaschinen	Notebooks	Fernsehgeräte
3	**Hohe Kosten der Reparatur im Kontext der Preise für Neuprodukte (Ökonomische Obsoleszenz)**			
3.1	Bei vielen Defekten erscheint eine professionelle Reparatur im Kontext der bestehenden Marktpreise für Neuprodukte als zu teuer.	X	X	X
3.2	Zu hohe Bauteilintegration, sodass immer ein großes und entsprechend teures Teil ausgetauscht werden muss. Außerdem schlechte Zugänglichkeit der Bauteile.	X	X	X
3.3	Keine Ersatzteile oder nur Originalbauteile erhältlich.	X	X	X
3.4	Zu hohe (Anfahrts-)Kostenpauschalen für die Servicetechniker.	X		(X)
4	**Trends und Wunsch nach neuen Funktionen (Psychologische Obsoleszenz)**			
4.1	Innovationen, neue Funktionen und Komfortversprechen der neuen Geräte veranlassen die Konsumentinnen und Konsumenten zu Neukäufen.	X	X	X
4.2	Sozio-demografische Faktoren, wie zum Beispiel Umzug in eine Wohnung mit einer Einbauküche oder Weitergabe der bestehenden Geräte an Jugendliche im Haushalt	X	X	X
4.3	Bessere Energieeffizienz der neuen Geräte, z.B. Ersatz eines Desktop-PCs durch ein Notebook	X	X	X

In Tabelle werden Strategien gegen die in Tabelle identifizierten Ausfall- und Ersatzursachen vorgeschlagen. Das Ziel ist dabei, alle unter einem Themencluster genannten Ausfall- und Ersatzursachen mit denselben Strategien zu adressieren[10]. Die einzelnen Strategien gegen Obsoleszenz sind in Kapitel **Fehler! Verweisquelle konnte nicht gefunden werden.** (**Fehler! Verweisquelle konnte nicht gefunden werden.** – **Fehler! Verweisquelle konnte nicht gefunden werden.**) detaillierter dargestellt. Außerdem wurde zu jeder einzelnen Strategie eine kurze Einschätzung zu möglichen Stärken und Schwächen abgegeben. Nicht zuletzt wurden die möglichen produktpolitischen Instrumente genannt, die für die Umsetzung der jeweiligen Strategien geeignet wären.

[10] Strategien gegen das Ursachen-Themencluster „*Trends und der Wunsch nach neuen Funktionen*“ werden im Rahmen dieses Vorhabens nicht erarbeitet. Zu diesem Themenkomplex hat das Umweltbundesamt andere Vorhaben zu den Themen soziale Innovation und kultureller Wandel beauftragt.

Tabelle 2 Identifizierung von Strategien gegen Obsoleszenz

Themencluster Obsoleszenz-ursachen		Strategien gegen Obsoleszenz	
1	Mangelnde mechanische und elektronische Robustheit	**Strategie 1: Lebensdaueranforderungen, Standardisierung, Normung**	
		S 1.1	Unterstützung von freiwilligen Lebensdauertests durch entsprechende Prüfnormen und unter kritischen Prüfbedingungen
		S 1.2	Verpflichtende Lebensdauertests unter kritischen Prüfbedingungen und Angabe Lebensdauer in den technischen Unterlagen und/oder als Teil der Verbraucherinformation
		S 1.3	Erarbeitung von Prüfmethoden und -normen zur Überprüfung der Lebensdauerprüfung für Bauteile und Geräte
		S 1.4	Untersuchung des Einflusses der realen Nutzungsbedingungen auf die Lebensdauer und Etablierung einer Norm mit kritischen Prüfbedingungen
		S 1.5	Design für Langlebigkeit
		S 1.6	Vermehrte Tests der Lebensdauer durch unabhängige Testinstitute, wie die Stiftung Warentest
2	Softwarebedingte Gründe	**Strategie 2: Mindestanforderungen an die Software**	
		S 2.1	Entwicklung von innovativen und modularen Software-Lösungen
		S 2.2	Grundlegende Software-Treiber müssen eine ausreichend lange Zeit vorgehalten bzw. aktualisiert werden
		S 2.3	Förderung von freien Soft- und Hardware-Initiativen sowie Schaffung von Rechtssicherheit zu deren Verwendung und Vermarktung
		S 2.4	Verpflichtende Hardware und Software Updates sowie volle Funktionstests
		S 2.5	Standardisierung, Fehlerdiagnosefunktion und neue Softwarelösungen
3	Hohe Kosten der Reparatur im Kontext der Preise für Neuprodukte	**Strategie 3: Reparaturfähigkeit**	
		S 3.1	Verbesserte Rahmenbedingungen für unabhängige und freie Reparaturbetriebe, einschließlich transparente Reparaturinformationen
		S 3.2	Pflichtvorgaben zur Vorhaltung von Ersatzteilen, einschließlich transparenter Informationen bezüglich der zu erwartenden Kosten für Ersatzteile
		S 3.3	Akkus und sonstige Verschleißteile müssen leicht auswechselbar oder reparierbar sein
		S 3.4	Veränderung der Kostenkalkulation für Reparaturen
		Strategie 4: Servicemodelle der Hersteller für eine Lebens- und Nutzungsdauerverlängerung	
		S 4.1	Leasing-Modelle (als eigentumsersetzende Nutzungsstrategie)
		S 4.2	Rückkaufvereinbarung
		S 4.3	Nachsorgebehandlung als Dienstleistung

Themencluster Obsoleszenz-ursachen		Strategien gegen Obsoleszenz	
4	Übergreifend: kürzere Nutzungsdauer durch Verbraucherinnen und Verbraucher	**Strategie 5: Informationspflichten, Verbraucherinformation**	
		S 5.1	Eindeutige Deklaration von Sollbruchstellen (im Sinne Sicherheitsfunktion), Verschleißteilen und Wartungsintervallen
		S 5.2	Verbraucherinformation zur Verlängerung der Nutzungsdauer

In Anbetracht der technologischen Weiterentwicklungen und Innovationen bei Elektro- und Elektronikgeräten stellen Mindestanforderungen an die Produktlebensdauer und Qualität, unabhängig vom Produktdesign und der Produktgruppe eine wichtige Strategie dar. Auch im Hinblick auf die Tatsache, dass in vielen Fällen die ökonomische Obsoleszenz zum Ende der Produktnutzung führt bzw. führen kann, erscheint eine zuverlässige Produktlebensdauer, innerhalb derer nicht oder nur in seltensten Fällen repariert werden muss, der richtige Weg. Um derartige Mindestanforderungen verlässlich entwickeln und nachprüfen zu können, bedarf es Standards und Messnormen. Zwar gibt es bereits etliche Standards und Normen für die verwendeten Bauteile zur Prüfung der Sicherheit und Gebrauchstauglichkeit von elektrischen und elektronischen Geräten. Es fehlen allerdings lebensdauerbezogene Prüfungen für Produkte. Die Erarbeitung geeigneter Testnormen ist möglich, erfordert jedoch viel Zeit (30-60 Monate) und Aufwand. Auf der anderen Seite bieten bestehende Messnormen und Standards auf der Komponentenebene erste Ansatzpunkte, obwohl diese primär zur Prüfung der Sicherheit und Gebrauchstauglichkeit von elektrischen und elektronischen Geräten entwickelt wurden. Die Nutzung und Anpassung der Messnormen und Standards auf der Komponentenebene ist aber auch deswegen sinnvoll, weil die produktbezogenen Lebensdauerprüfungen in der Praxis nicht für alle Produkte umsetzbar oder nur mit extrem hohem Kosten- und Zeitaufwand verbunden sind. Wichtig ist allerdings, dass die Auslegung der Geräte mit den realistischen Randbedingungen ihres Einsatzes konform ist. Gibt es hier Abweichungen, kann es leicht zu einer Überbelastung kommen und damit zu einem verfrühten Ausfall. Aus diesen Gründen bildet die Strategie „Lebensdaueranforderungen, Standardisierung und Normung“ den Kern der übergeordneten Strategien gegen Obsoleszenz.

Darüber hinaus könnten auch innovative Servicemodelle der Hersteller (z.B. Leasing, Rückkaufvereinbarung oder Nachsorgebehandlung) sowie verpflichtende Mindestanforderungen an die Software dazu beitragen, dass die technische Produktlebensdauer in der Praxis auch erreicht werden kann (z.B. durch Wiederaufbereitung für die Weiter- bzw. Wiederverwendung, garantierte Reparaturen durch die Hersteller oder verbesserte Abstimmung der Software und Hardwarelösungen miteinander). Maßnahmen zur Verbesserung der Verbraucherinformationen (z.B. ökologische Vorteile von langlebigen Produkten) und Erhöhung der Informationspflichten der Hersteller (z.B. eindeutige Deklaration von Verschleißteilen) sind weitere wichtige Instrumente, um die Kaufentscheidung zu Gunsten von langlebigeren Produkten zu beeinflussen.

Die Analyse der ökonomischen Obsoleszenz in dieser Studie hat gezeigt, dass die hohen Ersatzteil- und Personalkosten im Vergleich zu sinkenden Preisen für Neuprodukte in vielen Situationen die Reparaturbereitschaft verringern. Zusätzlich stellen steigende Produktkomplexität und hohe Integrationsdichte der modernen Produkte sowie ferngesteuerte softwarebedingte Fehlerdiagnosen unabhängige, nicht-herstellergebundene Reparaturbetriebe vor große Herausforderungen. Mit einer Strategie zur verbesserten Reparaturfähigkeit könnten u.a. Rahmenbedingungen für die Reparierfähigkeit der Produkte und den Erhalt der unabhängigen Reparaturszene in Europa geschaffen werden. Allerdings besteht noch Prüfbedarf über die Erfolgswahrscheinlichkeit einer solchen Strategie im Hinblick auf die oben dargestellten Herausforderungen. Aus Umweltgesichtspunkten ist es wichtig, dass Reparaturen möglich sind und von Endkunden auch in Anspruch genommen werden. Noch wichtiger sind jedoch Mindestqualitätsstandards und verlässliche Lebensdauerprüfungen und –angaben für die Produkte, damit Reparaturen gar nicht oder nur selten erforderlich werden.

Die im Rahmen dieser Studie vorgeschlagenen Strategien gegen Obsoleszenz zielen darauf ab, die Informationsasymmetrien zwischen Herstellern und Verbrauchern bezüglich der zu erwartenden Produktlebensdauer sowie der von Herstellern vorgesehenen Nutzungsintensitäten zu beheben. Die empfohlenen Strategien nehmen vor allem die Hersteller und Politik in die Pflicht, Transparenz bezüglich der zu erwartenden Produktlebensdauer zu erhöhen sowie Mindesthaltbarkeits- und Qualitätsanforderungen an die Produkte, Bauteile und Komponenten vorzuschreiben. Auf der anderen Seite sind aber auch Verbraucherinnen und Verbraucher aufgefordert, die Produkte im Sinne des Umwelt- und Ressourcenschutzes so lange wie möglich zu nutzen. Strategien gegen Obsoleszenz lassen sich demnach keineswegs von einem Tag auf den anderen umsetzen. Vielmehr sind sie als eine gesamtgesellschaftliche Aufgabe im Zusammenspiel zwischen Politik, Herstellern, Wissenschaft und Verbrauchern zu verstehen.

1 Introduction and Background

Products of the high-tech services economies of the 21st century have significant environmental impacts for two main reasons – firstly because the numbers of products have been increasing steadily, and secondly because of the relatively short product use times that can be observed in some cases. The resulting volumes of waste electrical and electronic equipment have considerable impacts on the environment and on society. In addition, the high rate of innovation for electrical and electronic equipment, especially for consumer electronics and ICT, in combination with falling prices for new appliances lead to shorter and shorter service lifespans for products. This means that the period in use is shorter than the technical lifespan. For example, there is empirical evidence that laptops often have a service lifespan of less than 3 years (Deng et al. 2011; Williams and Hatanka 2005). In many cases this is not because they have developed physical faults but because it is not practicable to expand the performance capability, e.g. by adding more memory or retrofitting a new hard drive or another mass storage device. In consequence, consumers increasingly choose to buy a new appliance even though the one they have could in principle be upgraded. This applies mainly for first users. Professionally used appliances frequently find a second use for private purposes or in schools.

The resulting waste electrical and electronic equipment and the increasingly short lifespans of products feature frequently in the public discussion of “obsolescence”. Whereas in earlier discussions of obsolescence in the 1960s and 1980s the resources were widely regarded as being virtually inexhaustible and little consideration was paid to the various substances used to produce goods, aspects such as material efficiency and resource conservation have now come to play an important role in the discussion.

Potential supply bottlenecks for various metals have become highly relevant for electrical and electronic equipment. Notebook computers, smartphones, flat screens, etc., contain significant quantities of noble metals such as gold, silver, and palladium. The hard drives of laptops and other computers contain relevant amounts of the rare-earth metals neodymium and praseodymium (permanent magnets). In addition, tantalum is contained in the micro-capacitors used in laptops, mobile phones, and televisions. In LED illuminants, which are also used in flat screens there are significant quantities of indium. An overview of the quantities of metals used is provided in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 3 Metals contained in products sold in Germany in 2010 for use in private households (flat screens, laptops, smartphones and estimates for LED illuminants)

Metal		Contents [kg] in all products sold in Germany in 2010			Estimate [kg] if LEDs replaced		Used in
		Flat screens	Laptops	Smart phones	70% of light bulbs	all other illuminants	
Cerium	Ce	30	1		120	300	Fluorescent lighting
Dysprosium	Dy		430				Voice coil actuator
Europium	Eu	50	<1		40	90	Fluorescent lighting
Gadolinium	Gd	10	5		910	2,260	Fluorescent lighting
Gallium	Ga	15	10		1,980	4,890	Semiconductor chips

Metal		Contents [kg] in all products sold in Germany in 2010			Estimate [kg] if LEDs replaced		Used in
		Flat screens	Laptops	Smart phones	70% of light bulbs	all other illuminants	
Gold	Au	1,645	740	230			PCBs, contacts
Indium	In	2,365	290		1,800	3,200	Display interior coating; Semiconductor chips
Cobalt	Co		461,000	48,500			Lithium-ion batteries
Lanthanum	La	40	<1				CCFL[11]-background lighting
Neodymium	Nd		15,160	385			Permanent magnets
Palladium	Pd	465	280	85			PCBs, contacts
Platinum	Pt		30				Hard drive disks
Praseodymium	Pr	<1	1,950	80			Voice coil actuator, loudspeakers; CCFL-background lighting
Silver	Ag	6,090	3,100	2,350			PCBs, contacts
Tantalum	Ta		12,065				Capacitors
Terbium	Tb	14	<1				CCFL-background lighting
Yttrium	Y	680	12		1,950	4,810	Fluorescent lighting

Source: Buchert et al. 2012

Extracting and processing metals involves considerable land use, and material and energy inputs, as well as causing high environmental impacts. In many places the extraction of gold and silver is associated with high environmental and social costs. The large-scale extraction of rock, energy-intensive crushing, and extraction with cyanide or mercury amalgamation are only some of the typical causes of the far-reaching impacts on humans and the environment. Producing one tonne of gold causes emissions of approx. 18,000 t CO_2e with a cumulative resource demand[12] of some 740,000 t (IFEU 2011).

According to a study of Oeko-Institut (Tsurukawa et al. 2011), more than half the cobalt used worldwide in lithium-ion batteries for smartphones or tablet PCs is extracted under life-threatening conditions in the Democratic Republic of Congo. More than 100 people die there every year in the process. In addition, the ore often contains uranium and other heavy metals, so that the mine workers are exposed to radiation and other serious health hazards. Child labour is widespread. Some 19,000 to 30,000 children below 15 years of age mine the ore or wash and sort the extracted minerals.

[11] Cold cathode fluorescent lamps

[12] The cumulative resource demand is made up of the demand for fuels, metal ore, and other minerals.

Inappropriate recycling measures to recover these metals can also lead to considerable negative impacts on humans and the environment, for example as a result of the use of mercury to recover gold from electronic waste (Prakash & Manhart 2010).

With the current state of recycling technology in Germany, a large proportion of the critical resources contained in electronic waste are lost, as is shown by a study of Oeko-Institut (Buchert et al. 2012; **Fehler! Verweisquelle konnte nicht gefunden werden.**). When producing new electrical and electronic appliances it is then necessary to use new primary resources, with higher environmental and social costs than the secondary recovery of the same materials.

Table 4 Recovery of important resources from laptops (Germany)

Metal		Contents in all laptops sold in Germany in 2010 [t]	Losses in collection of waste	Losses in pre-treatment	Losses in final treatment	Recovery in Germany [t]
Cobalt	Co	461.31	50%	20%	4%	177
Neodymium	Nd	15.61	50%	100%	100%	0
Tantalum	Ta	12.06	50%	100%	5%	0
Silver	Ag	3.11	50%	70%	5%	0.443
Praseodymium	Pr	1.94	50%	100%	100%	0
Gold	Au	0.74	50%	70%	5%	0.105
Dysprosium	Dy	0.43	50%	100%	100%	0
Indium	In	0.29	50%	20%	100%	0
Palladium	Pd	0.28	50%	70%	5%	0.040
Platinum	Pt	0.028	50%	100%	5%	0
Yttrium	Y	0.012	50%	40%	100%	0
Gallium	Ga	0.010	50%	40%	100%	0
Gadolinium	Gd	0.0048	50%	40%	100%	0
Cerium	Ce	0.00069	50%	40%	100%	0
Europium	Eu	0.00028	50%	40%	100%	0
Lanthanum	La	0.00008	50%	40%	100%	0
Terbium	Tb	0.00003	50%	40%	100%	0

Red = process optimisation required Blue = research required

Source: Buchert et al. (2012)

Among manufacturers, economists, scientists, politicians, and other interested parties there has been an intensive debate on material obsolescence for many decades. Discussions first came to a head at the end of the 1920s, then in the 1960s, and again in the 1980s. Reviewing scientific and journalistic publications, the discussions about the various forms of obsolescence appear to have been conducted for various reasons, but to have ebbed again after some years. Over the past five years or so there has been a revival of the discussion about obsolescence, and in particular material and functional obsolescence. Attention has focussed on the concept of planned obsolescence, and there have been controversial debates about a clear definition. In the popular media, planned obsolescence is presented as the intentional inclusion of weak points in products by manufacturers who wish to shorten their operating life. The sole aim is assumed to be the development of a product that will force the customer to buy a replacement prematurely. This view of planned obsolescence is based on the premise that the product as a whole had not reached the end of its technical lifespan, and that the consumers would have preferred to continue using their product longer.

Initially, media reports were published in Germany, Austria and Switzerland, but more recently coverage has extended to other European countries, EU organisations, and also worldwide. Numerous television documentaries, special reports in newspapers and magazines have since taken up the topic. In France, the energy transition bill passed in the National Assembly on 22.07.2015 included measures against planned obsolescence. It is planned to introduce a legal definition of programmed obsolescence[13] and include penalties for transgressions of up to two years in prison and fines of up to EUR 300,000 or 5% of the annual turnover of a company. It is also proposed that manufacturers should provide voluntary consumer information about the lifespan of a product[14].

On the other hand, there is consensus in the scientific community that the product lifespan is generally a planning parameter that serves as an orientation for product designers and developers. The technical design of a product for an appropriate lifespan, taking environmental and economic considerations into account, could therefore also be regarded as planned obsolescence, but it is based on a very different premise than the coverage in the popular media.

Furthermore, “psychological obsolescence” may be equally relevant. The underlying assumption in this case is that consumers are more open to novelties, that they appreciate innovative companies, and purchase new products that offer improved functions and utility. Where there is a real need for a new acquisition, the orientation towards innovation is to be welcomed. However, consumers tend to make new purchases even though the product they already have still works, resulting in high resource consumption.

The question of reparability of products is discussed in terms of “economic obsolescence”, which not only includes the technical possibility of carrying out repairs but also the availability of repair services and the costs involved. A comparison with the cost of a new purchase is in most cases a key factor when it comes to deciding whether to carry out repairs. This is one of the reasons for the changing useful service lives of products.

Much of the media coverage is anecdotal in nature. In general, there are gaps in the data concerning obsolescence (material, functional, psychological, and economic) and there is a shortage of scientific research in this field. This study aims to describe the various forms of obsolescence with specific examples and to provide improved data for assessing the phenomenon of obsolescence, taking electrical and electronic products as an example.

[13] Article L 213-4-1 of the “Codes de la Consommation” defines programmed obsolescence as “l'ensemble des techniques par lesquelles un metteur sur le marché vise à réduire délibérément la durée de vie d'un produit pour en augmenter le taux de remplacement” (Assemblée Nationale 2015).

[14] Assemblée Nationale (2015): TEXTE ADOPTÉ n° 575, Projet de Loi - relatif à la transition énergétique pour la croissance verte, Article 99, http://www.assemblee-nationale.fr/14/ta/ta0575.asp; accessed: 24.11.2015

2 Goals of the project

The main goal of the project is to produce a sound data base for describing and assessing the phenomenon of obsolescence and trends in product lifespans and use times, and on this basis to develop effective strategies against obsolescence or to achieve reliable minimum product use times. The focus is on electrical and electronic equipment for use in private households.

The following objectives will be pursued:

1. Collection of statistical data and analysis of trends on technical life- and use-times of electrical and electronic equipment;
2. Systematic description of the causes of obsolescence in electrical and electronic equipment;
3. Conducting case studies for three product groups in order to collect more data and identify measures to achieve extended lifespans or a reliable service life for the selected product groups;
4. Comparative life-cycle assessment and life cycle costing in three product groups for products with shorter or longer lifespans;
5. Identification of cross-cutting strategies and instruments against obsolescence and for increasing product lifespans as well as use times and reaching a reliable minimum product lifespan.

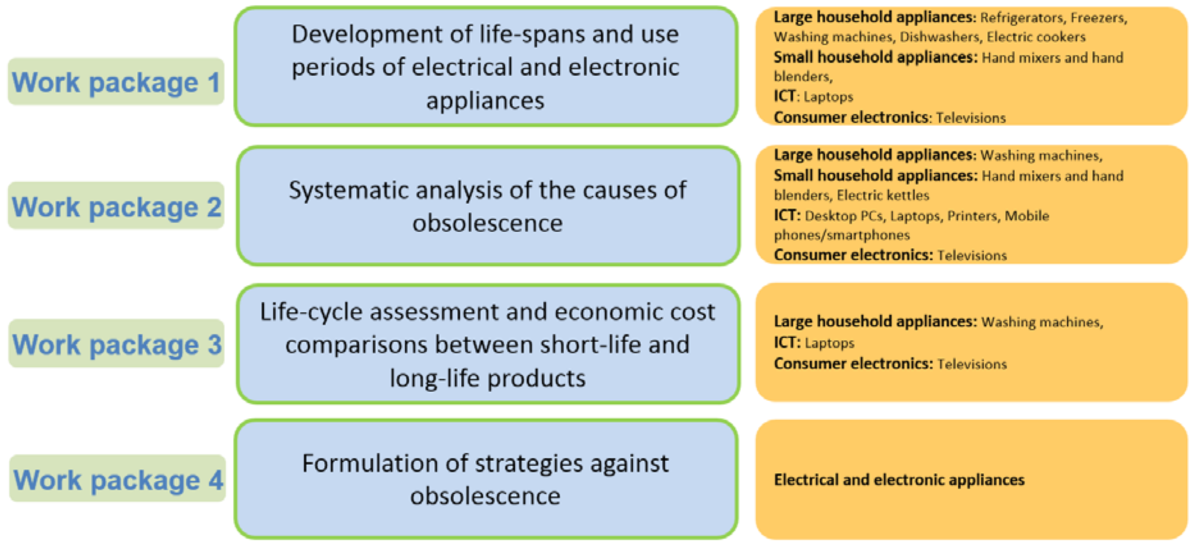
The study covers the following product groups:

- ► Large household appliances
  - Refrigerators
  - Freezers
  - Washing machines
  - Laundry driers
  - Dishwashers
  - Electric cookers
- ► Small household appliances[15]
  - Hand mixers and hand blenders
  - Electric kettles
- ► Information and communications technology
  - Desktop-PCs
  - Laptops
  - Printers
  - Mobile phones/smartphones
- ► Consumer electronics
  - Televisions

[15] Chapter 5 contains data for hand mixers and blenders. Electric kettles are considered in the causal analysis in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**. In Section **Fehler! Verweisquelle konnte nicht gefunden werden.**, tests of the German consumer association Stiftung Warentest are evaluated to identify the most frequent causes of defects in electric toothbrushes, espresso machines, steam irons, and vacuum cleaners.

The design of the research project is shown in Figure 1.

Figure 1 Research design



3 Definitions

In this study, the following terms and concepts are used as defined:

Obsolescence: The ageing (natural or artificial) of a product so that it no longer satisfactorily meets the intended need. It is used to refer either to: 1) Ageing or wear in general, or 2) Premature ageing or wear. The latter presupposes the expectation of a lifespan, which is developed as part of a societal process. Consumers may have differing views in this regard and they are subjected to a variety of influences[16].

The following types of obsolescence are distinguished:

1. **Material obsolescence**: The result of the insufficient performance of materials and components. The product ageing may, for example, manifest itself as the (overly rapid) worsening of robustness as a result of rusting, corrosion, degradation or transformation (Bertling et al. 2014).
2. **Functional obsolescence**: the result of rapidly changing technical and functional demands on a product (e.g. the interoperability of software and hardware between different electronic appliances). Functional obsolescence is heavily influenced by the differing interests of software and hardware producers (Bertling et al. 2014).
3. **Psychological obsolescence**: The premature ageing and discarding of a functioning product as a result of fashion, new technological trends, or changing patterns of consumption (after Bertling et al. 2014).
4. **Economic obsolescence**: The loss of the useful properties of a product because the costs of the resource inputs required to maintain or repair the product are excessive or the difference to the cost of a new product is unfavourable. Reasons may be the short product development cycles, rapidly falling prices, repair-unfriendly design, high repair costs, or the lack of spare parts, special tools, and repair services.

Lifespan: The average period from the first distribution of an appliance until a terminal defect.

Period of use: How long an appliance is used for its intended purpose. This includes use by subsequent holders after the appliance has been given away or sold.

Period of first use: How long an appliance is used by the first user.

Residence time: The time from the purchase of an appliance until its collection for disposal. (This includes not only the period of use but also storage without use.)

Rated breaking point: A constructive, mechanical or physical measure or design element which ensures that in the event of overloading or damage this element will fail in an anticipated fashion, averting or minimising possible damage to other components or the entire system.

Weak point: A mechanical or electrical element in a construction that is particularly liable to become defective, heavily influencing the lifespan of a product.

[16] According to the German Civil Code (section 434), a buyer may expect a product to be suitable for the customary use, and of a quality that is usual in things of that kind. This includes characteristics which the buyer can expect from the public statements and advertising of the producer.

4 Methods to assess the lifespan, use and residence times of products

Various methods have been developed to assess the technical lifespan of consumer goods. Depending on the specific interests of the scientific discipline in question, these methods differ in terms of the precision of their findings and their scope for interpretation. They also differ with regard to the costs involved in acquiring and preparing the data, as well as in terms of the questions addressed concerning lifespan, use and residence times.

The choice of survey methods depends among other things on the goods concerned, the market situation, and the background of the researchers. Lifespan data are important for analyses in a range of sectors such as marketing and market research, product planning and design, material flow analyses, or waste management (e.g. for predicting the future demands on waste disposal plants).

The following section presents various methods and sources of information for determining lifespan data and their usefulness for this study, in particular for:

a) The changes in lifespan over time,

b) The factors that ended the lifespan, and

c) The approaches to extending a product lifespan.

4.1 Internet forums and social media

Anybody searching on the Internet or social media for information about which new product to buy will find users make very different and even contradictory statements about the durability of their appliances. The reports in Internet forums, Wikipedia entries, social media or blogs about quality characteristics, and assessments of the lifespan of products can differ considerably. The subjective experience of each individual reflects the different conditions under which they use the product, leading to very diffuse results regarding the lifespan of appliances.

For example, a search of various Internet forums about the lifespan of lap-top computers produced the following results.

Table 5 Discussions of the lifespan of laptops on Internet forums

Comment / Article	Stated lifespan / Comment	Source / Date
General: Lifespan depending on temperature of processors and graphics chip Ventilation Battery life Fluctuations in mains power supply Recommendations: Clean ventilator Apply fresh thermal paste Check whether CPU adapts to use (clock speed, power consumption, temperature)		http://www.hifi-forum.de/viewthread-247-401.html, Thread from 2011, http://www.gutefrage.net/frage/haltbarkeit-von-dell-laptops, 2013
Business laptops	2.5 years, appliance works with decreasing performance, battery life very short	http://www.hifi-forum.de/viewthread-247-401.htm, Thread from 2011

Comment / Article	Stated lifespan / Comment	Source / Date
Consumer laptops	"After 2 years - bin it" "3 years, then swap it because of poor performance" "6-7 years, if only used occasionally" "If well cared for, 10 years easily"	http://www.hifi-forum.de/viewthread-247-401.html, Thread from 2011 https://forum.vis.ethz.ch/showthread.php?6990-Lebenserwartung-von-Notebooks, Thread from 2005
Further branded laptops	"5 years guarantee possible, good service" "12 years, used as server"	www.gutefrage.net/frage/haltbarkeit-von-dell-laptops, Thread from 2013

Source: Our Internet research, Links accessed on 23.03.2014

Nevertheless, even if these differing reports appear to be imprecise and anecdotal, they can give some impression of the quality of a product. Depending on personal preferences, differing quality aspects will be referenced in the reports, and these may be relevant for a reader's purchase decision.

In addition, various aspects of utilisation are addressed on the Internet forums that can result in an increase in the lifespan of appliances. With regard to the maintenance and care of laptops, attention is drawn in particular to careful handling and the need for regular maintenance or cleaning of hard drives, batteries and fans. Contradictory and often incorrect advice can be found on the measures to be implemented in specific cases. An illustrative example is the recommendations made on how to extend the lifespan of laptop batteries. Myths include applying a special adhesive foil to extend the durability, or fully discharging and recharging of the battery to avoid memory effects, although these only occur with outdated battery technologies (e.g. nickel-cadmium) and no longer apply for lithium-ion batteries[17].

As part of this study of changes in the lifespan of products over time and the factors that can affect the useful life of products, it is important to have reliable statements in order to be able to develop effective and reproducible measures for extending the lifespan. Contributions to Internet forums and social media do not meet these requirements and therefore they cannot be used here.

4.2 Consumer portals and campaigns

Consumers react very sensitively to reports about production faults and product recalls. But they find themselves caught up between information and disinformation. Attempts are made with advertising and commercial marketing activities to stimulate purchase impulses and to serve real or perceived needs, while at the same time producers are very secretive about their production processes. Consumer information portals and awareness-raising campaigns, e.g. by NGOs, attempt to introduce more transparency. However, consumers remain confronted with large amounts of seemingly impenetrable information from which to extract reliable advice.

In Germany, the consumer campaign "*Murks? Nein Danke*!"[18] offers consumers the opportunity to present their own experience with products and planned obsolescence issues (Schridde et al. 2012). Reasons for failures given on the portal include:

[17] See http://www.tomshardware.de/Li-Ionen-Akkus,testberichte-239772-7.html

[18] "Rubbish – no thanks"; see www.murks-nein-danke.de

- Due to components:

  1. Undersized aluminium-electrolytic capacitors (e-caps) lead to the failure of power units
  2. Connections, e.g. broken cables at the plug of headphones
  3. Material fatigue, e.g. when plastic gear wheels are used in hand mixers
  4. Material failure of heating elements in washing machines (integrated fuses, corrosion)
  5. Material fatigue in bearings and inadequate shock absorption leading to vibrations (e.g. of washing machine drums)
  6. Replacing one material with another, e.g. switching from stainless steel to plastic suds container in washing machines
  7. Material substitution from metal to plastic in switches (e.g. power switch on a device)
  8. Plastic parts that break under impacts (e.g. if the product is dropped)

- Constructional faults:

  1. Permanently installed batteries mean that an appliance can no longer be used or loses its mobile operability once the battery no longer has sufficient charging capacity
  2. A permanently bonded housing hinders repairs
  3. Plastic studs and eyelets that easily break off or come loose
  4. Requirement to replace entire units rather than individual components
  5. Failure of electrolytic capacitors (e-caps) because they are installed too close to a heat source
  6. Relay in dishwasher overheats and the solder melts
  7. Power sockets only soldered in place (e.g. for laptops), leading to total economic write-off on failure
  8. Drop counters in ink jet printers: mechanical counters that report when a certain number of pages have been printed and switch off the printer, because the manufacturer assumes that the ink pad reservoir is full
  9. Special screws and tools impede repairs
  10. Laptop fan blocks with dust and is difficult for the user to clean

From a qualitative perspective, the study of Schridde et al. (2012) and the portal make an important contribution for identifying characteristics of inferior and short-lived products. However, research on the portal about significantly reduced lifespans of products do not on the whole lead to sound results that would provide a basis for generalisations.

4.3 Product tests

Manufacturers and dealers are most concerned about product tests, such as those carried out regularly by consumer associations, and on occasion they can resort to taking legal action. In Germany, the product tests of the Stiftung Warentest consumer association cover key aspects of the suitability of products for a specific use on the basis of objectified characteristics that make it possible to evaluate and compare the effectiveness and the environmental impact of the products being tested (see www.test.de). Test results of the consumer association have considerable influence on consumer choices in Germany and a good result is important for the promotion of a product. In contrast, a poor assessment can lead to plummeting sales, and in some cases companies try to lodge claims for damages against Stiftung Warentest.

The tests focus on the cost-effectiveness for the consumers, and a test winner is determined on the basis of a set of criteria. Lifespan tests are not carried out systematically for all product groups. Criteria for extending the lifespan of products, such as reparability, storage of spare parts, or the service quality in warranty cases, are not usually taken into consideration (Stiftung Warentest 2013). When durability tests are carried out, the consumer association only tests whether each appliance works for a specified minimum period. They do not test how much longer the appliance would still remain in working order. And the selected products in each case do not allow fully representative conclusions to be drawn for the product group as a whole.

According to Stiftung Warentest, although weaknesses are determined in the durability tests, it is not possible to identify either planned measures to shorten lifespans, or other product characteristics or predetermined breaking points that regularly terminate the lifespan.

4.4 AfA tables of public institutions

In company accounting, it is important to know the expected lifespan of products in order to calculate the mean annual rate of depreciation of investment assets. The annual rates of depreciation are key parameters for internal financial controlling and determining annual reinvestment expenditures. In Germany, annual depreciation can be booked as expenditures and thus reduce tax liabilities. The typical period over which a type of asset can be written off is specified in “AfA” depreciation tables issued by the German Federal Ministry of Finance (BMF 2012). The depreciation periods in the AfA Tables are based on the experience of accountants and auditors and are intended to reflect the real rates of wear of the assets. However, the values in the AfA Tables are not legally binding. Shorter depreciation periods can be adopted if justified by the special conditions of use.

The depreciation in accordance with the AfA Tables does not constitute an incentive for further investments. Whether a decision is made to continue to use or to replace a product after it has been fully written off is a commercial decision and depends on the specific economic situation of the user.

The usual period of use is to be given “in accordance with the operating situation” (Gabler 2014) and should “correspond to the technical lifespan that is to be expected under the specific operating conditions” (BFH 1997). The depreciation period for an economic asset is therefore not determined solely by the actual useful life. The technical useful life of a product depends on its quality, but also on both the usual operational lifespan, the technical performance and the extent to which the good is used.

In addition to sector-specific depreciation tables, AfA Tables are provided for generally used assets (AfA-AV). These were issued in the year 2000 and give typical periods of use for goods, like the examples shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.[19]

[19] According to a response received from the German Federal Ministry of Finance, no revision of the tables was planned during the project period.

Table 6 Depreciation periods according to the AfA-AV Table (extract)

Asset	Usual period of use (in years)
Mobile telephones	5
Desktop PC, laptops, printer, scanner, monitors	3
Televisions, monitors	7
Dishwashers	7
Washing machine	10
Laundry drier	8
Refrigerators	10
Microwave	8

Source: BMF (2000)

4.5 Lifespan in the waste management sector

In the waste management sector, the lifespan of products plays an important role when assessing future amounts of waste and providing suitable waste disposal capacity. The complexity of the chain of waste generation, collection, transport, and recycling or disposal makes long-term planning a necessity. Maintaining or increasing disposal capacities involves high levels of investment, and the waste management processes must be adapted to suit the amounts of waste generated. In particular, it is necessary to determine as precisely as possible the future quality and quantity of the various waste fractions.

Waste management requires sufficiently precise data for determining future waste quantities. The statistical basis is provided by sales figures for the products at the point of sale, the consumers goods held by households and companies, and the lifespans of the goods (Wang et al. 2013). If these data are available with sufficient accuracy, or can be collected at reasonable expense, then these can be used to calculate the quantity and composition of future waste by means of an input-output analysis (IOA).

Determining precise lifespan data represents a key problem. In the following, various approaches are considered. Lifespan is used here in a general sense, without distinguishing between products that are still functioning on disposal, and products that are disposed of because they are defective.

4.5.1 Methods for waste prediction

Methods for calculating future quantities of waste not only place differing demands on data quality, but also take into account the requirements for different market settings. A distinction is made between saturated and dynamic markets. With a saturated market, a simplifying assumption can be made that every new product replaces a decommissioned old product (Chancerel 2010).

Fehler! Verweisquelle konnte nicht gefunden werden. shows some of the methods used in the literature on input-output analysis (IOA). Input data on lifespans can be prepared in different ways. The lifespan can be included as a temporally invariant average, or in the form of temporal distributions in various phases. The table shows the types of market situation (saturated or dynamic) for which the model can be used, and the expected precision of the estimates of future waste quantities.

Table 7 Overview of methods for estimating future waste potential

Method	Lifespan data	Market situation		Precision of estimate
		Saturated	Dynamic	
Simple delay	Average value	X		medium
Distribution delay	Distribution function	X	X	high
Carnegie Mellon	Average value	X	X	high
Batch leaching	Average value	X		low

Source: Our presentation, after Chancerel (2010) and Wang et al. (2013)

The Simple Delay Method considers future waste as the delayed outcome of product sales at a certain time. Lifespan data are determined here as the average values for each product group from the purchases at the point of sale. The expected precision of the estimate is only moderate, but the advantage is the comparatively low cost for acquiring the necessary data.

The Distribution Delay Method places high demands on the analysis of the lifespan and is considered in more detail in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

The Carnegie Mellon Method considers the sold products over various use phases (first use in the household, re-use, and the unused retention in the household), followed finally by an end-of-life inspection in the recycling plant or at the waste depot. This method requires considerable knowledge about typical consumer behaviour, with comparatively high costs for acquiring the necessary data.

The Batch Leaching Method[20], which only allows conclusions to made about a saturated market, also uses details about average lifespans of the appliances in households and businesses collected, on the assumption of a linear age distribution. This results in imprecise results but involves relatively low efforts for data collection (Wang et al. 2013).

In general, the following data sources could be used for lifespan data:

- Consumer surveys of the age of discarded products and the current age range of the appliances in households,
- Ownership levels of appliances at the beginning and the end of a certain period,
- Sorting and analysis of waste flows in recycling plants.

On the basis of a case study in the Netherlands, Wang et al. (2013) describe a multivariate analysis that brings together data about sales, household ownership levels, and lifespan data. A comparison of the predictions of waste figures in the Netherlands on the basis of this “Sales-Stocks Lifespan Model” with the results of other methods indicates that the results lack precision, presumably due to the imprecise nature of the data.

[20] This method is also referred to as the Phase-C method (Waltemath 2001).

4.5.2 Distribution Delay Method (Weibull Functions: distribution functions for representing lifespan data)

In order to estimate future quantities of waste by means of the **Distribution Delay Method,** the sales of products are linked to the probability of their becoming unusable over the years after the product first came onto the market. The probability of failure over time is estimated using a Weibull distribution function.

The Weibull distribution function describes the probability of failure or the end of the useful life of a class of product. Instead of the lifespan, other performance parameters can be used, e.g. the number of switching cycles, or the hours of operation.

The Weibull distribution is dependent on a scaling factor and a shape parameter. The scaling factor is interpreted in engineering as the inverse of the lifespan characteristic, i.e. the period within which 63.2% of the investigated appliances of a product series have failed (Wilker 2010).

The shape parameter determines the slope variations of the Weibull distribution. It is generally possible to identify different phases of failure (Wilker 2010):

- Phase I: Early failures (falling failure rate: shape parameter < 1)

  Early failures can be caused by construction and production errors, faulty software, material defects, or defective components received from suppliers. Frequent early failures are an indication of inadequate quality control.

- Phase II: Random failures (constant failure rate: shape parameter = 1)

  Random failures occur during the characteristic useful life and are attributable to maintenance and operational errors, or to mechanical effects, e.g. vibrations.

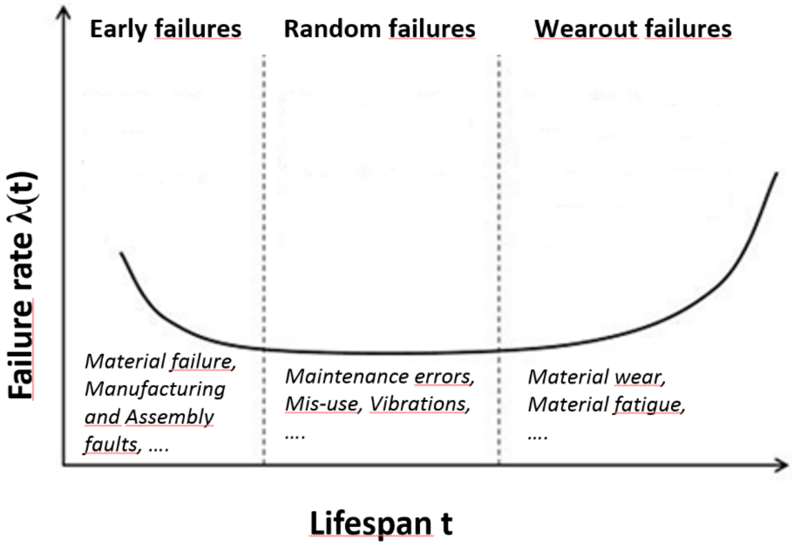
- Phase III: Wear-out failures (increasing failure rate: shape parameter > 1)

  Wear-out failures occur in the late life of a product and are attributable to material ageing and fatigue. The maximum period of use of a product is determined by the shortest-lived component.

These phases are represented in a so-called bath tub curve (Figure 2). The x-axis shows the lifespan and the y-axis shows the failure rate. The bath-tub curve describes the failure rate for the entire product population, so that it is not possible to use the graph to predict the failure behaviour of an individual product.

When designing product for a theoretically optimised lifespan, the aim would be for all components to fail simultaneously at the beginning of Phase III. Strategies to extend the lifespan also target this transition point, but focus on repair measures such as replacing components that are liable to wear out.

Figure 2 Bath-tub curve of failures (Weibull distribution)



Source: Our presentation

4.6 Scientific publications

4.6.1 Data survey in the Netherlands

Bakker et al. (2014) processed the lifespan data from the Dutch case studies (Wang et al. 2013) and investigated how the lifespan of electrical and electronic devices changed between 2000 and 2005. As shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, in most cases the lifespans fell over this five-year period.

Table 8 Median lifespans of EEEs in the Netherlands 2000 and 2005

Product category	Median lifespan in years, 2000	Median lifespan in years, 2005	Change
Compact fluorescent lamps	7.4	7.7	+3%
Flat screen television	10	10	0%
Vacuum cleaner	8.1	8	-1%
Laundry drier	14.5	14.3	-1%
Refrigerators	14.2	14.0	-1%
Dishwashers	10.7	10.5	-2%
Small IT devices and ancillaries	4.5	4.4	-2%
Tools	9.8	9.6	-2%
Toys (small)	3.8	3.7	-3%
Mobile phones	4.8	4.6	-3%
Washing machines	12.1	11.7	-3%
Laptops	4.3	4.1	-5%

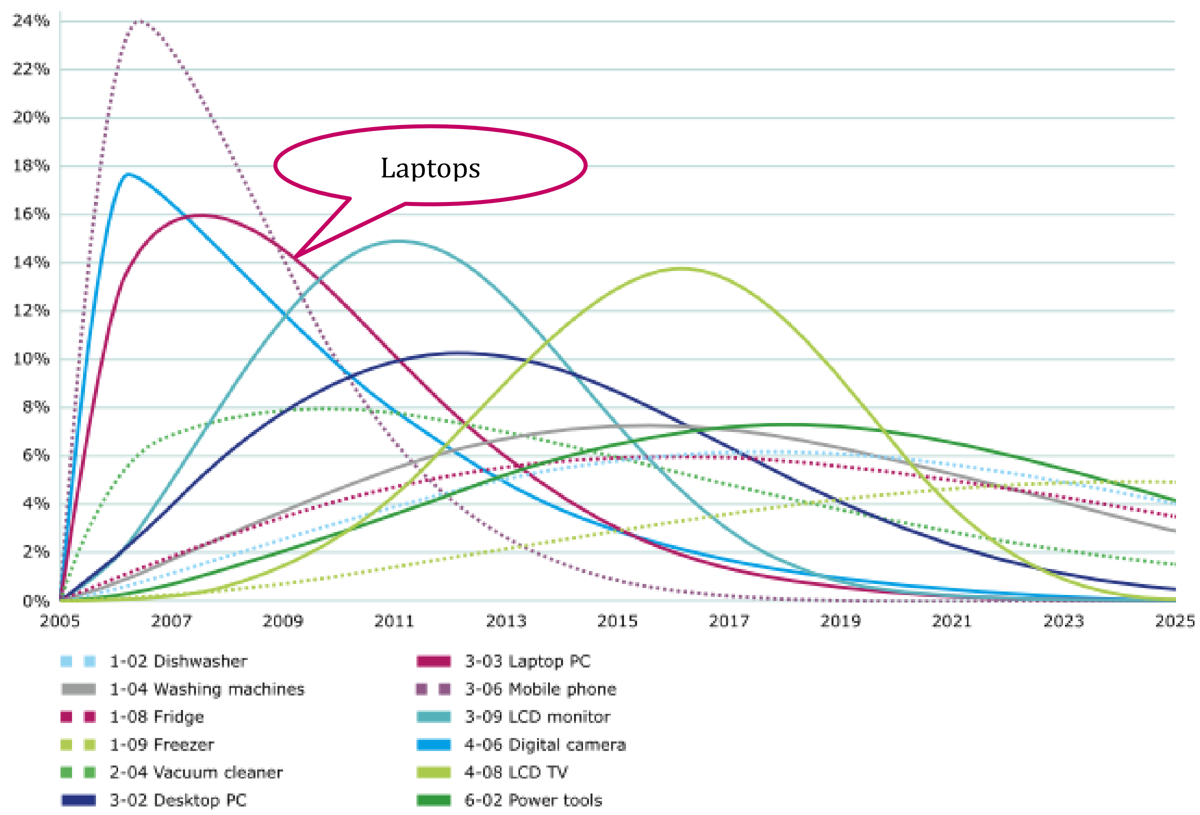
Product category	Median lifespan in years, 2000	Median lifespan in years, 2005	Change
Electric kettles, coffee machines	7.0	6.4	-9%
Printers	9.0	8.2	-11%
Microwaves	10.9	9.4	-15%
Small consumer electronics and ancillaries	9.4	7.8	-20%

Source: Bakker et al. (2014)

The lifespan data used in the case studies (**Fehler! Verweisquelle konnte nicht gefunden werden.**) were collected in two consumer surveys (Hendriksen 2007; 2009). A total of 6000 Dutch households were asked about the current age of appliances they owned and of old appliances they disposed of as well as future new acquisitions, covering 90 product categories. The results were cross-checked by direct interviews of selected representative households and validated by analysis of flows at recycling plants.

A further Dutch study (Huisman et al. 2012) analysed the residence times of products acquired by private households in 2005 (Figure 3). It is not possible here to distinguish between the use phase and the residence time in the household.

Figure 3 Residence times of EEEs put on market in 2005 (% discarded per year)



Source: Huisman et al. (2012)

Figure 3 shows for laptops that after two years some 16% of the appliances put on the market in 2005 had been discarded.

Huisman et al. (2012) evaluated detailed data about products put on the market between 1990 and 2010 and found the following declines in the residence times of equipment between the year 2000 and 2010:

- 17% for monitors
- 12% for small household appliances
- 10% for IT and telecommunications appliances
- 7% for large household appliances
- 4% for refrigerators and freezers

As possible reasons for the negative trend of lifespan data, Bakker et al. (2014) propose that for some product groups the shorter (technical) lifespan could be intended by the manufacturer, i.e. presumably planned obsolescence. In other cases, shorter periods of use are a result of technical progress and new legislation, which lead to a premature end of the product use (psychological and functional obsolescence).

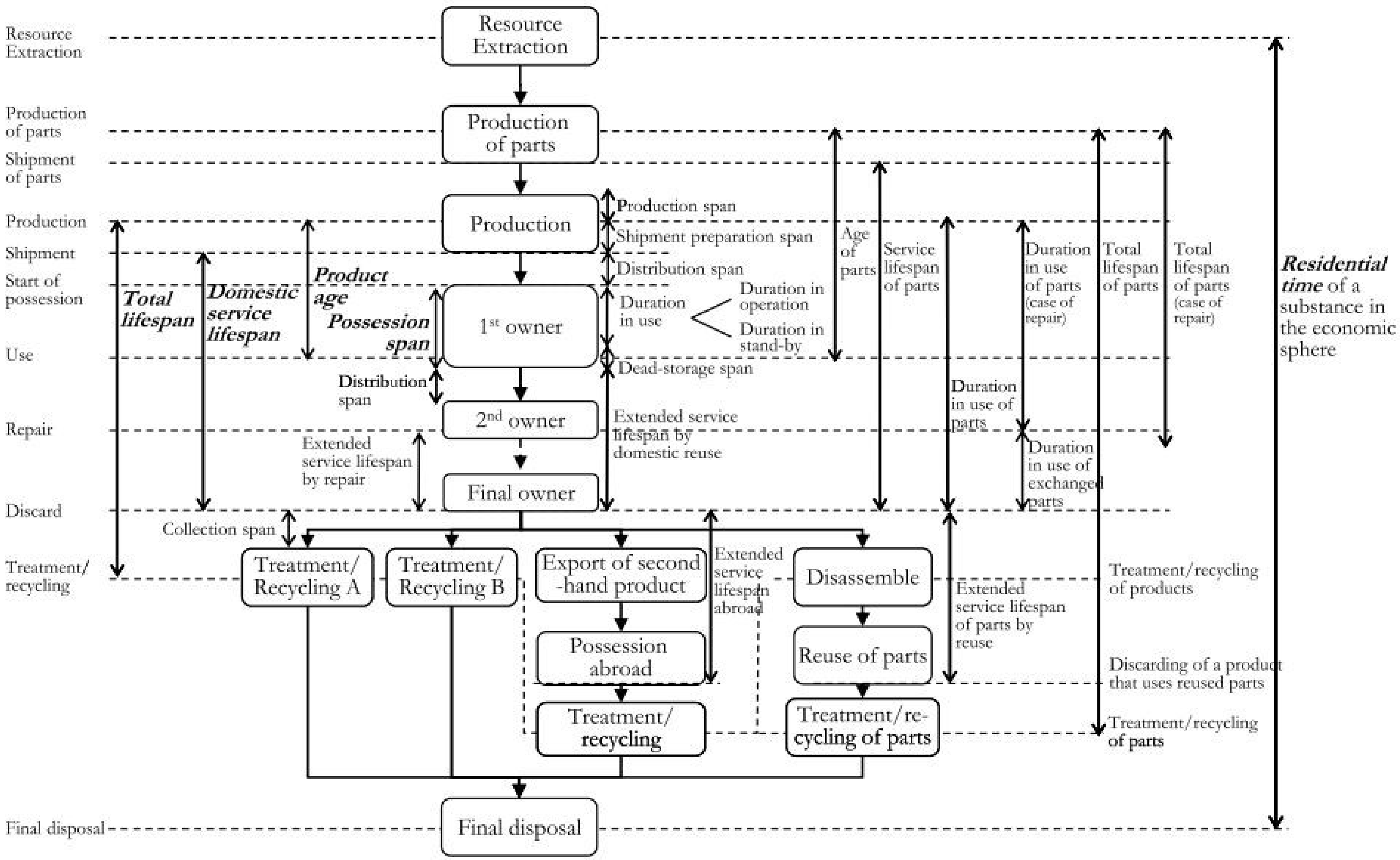
The authors also hypothesise that a further important factor explaining the downward trends in lifespans over the selected period could be the socio-economic development, i.e. consumers tend to make new purchases during an economic upswing, but are more likely to defer purchases during a downturn in the economy, due to a decline in purchasing power or increasing uncertainty about future developments.

4.6.2 Data survey in Japan

A further important basis for the Dutch investigation of the lifespans of electrical and electronic equipment in waste flows is provided by the lifespan database of the Japanese National Institute for Environmental Studies. The “Lifespan Database for Vehicles, Equipment and Structures (LiVES)” contains more than 1,300 datasets from various countries (Murakami et al. 2010). The data was first categorised in terms of a uniform terminology. The authors distinguish between:

- Residential time: The period during which a good or its material components circulate within the economic sphere, i.e. the period between resource extraction and final disposal,
- Total lifespan: The time between production and treatment recycling, including further use and re-use phases, also including shipping and distribution without use,
- Domestic service lifespan: the period of use of a good, including further use and re-use,
- Possession span: The duration of the first ownership,
- Duration in use: The period of the first ownership in which the good was being used

Figure 4 Overview of lifespan terminologies for consumer goods



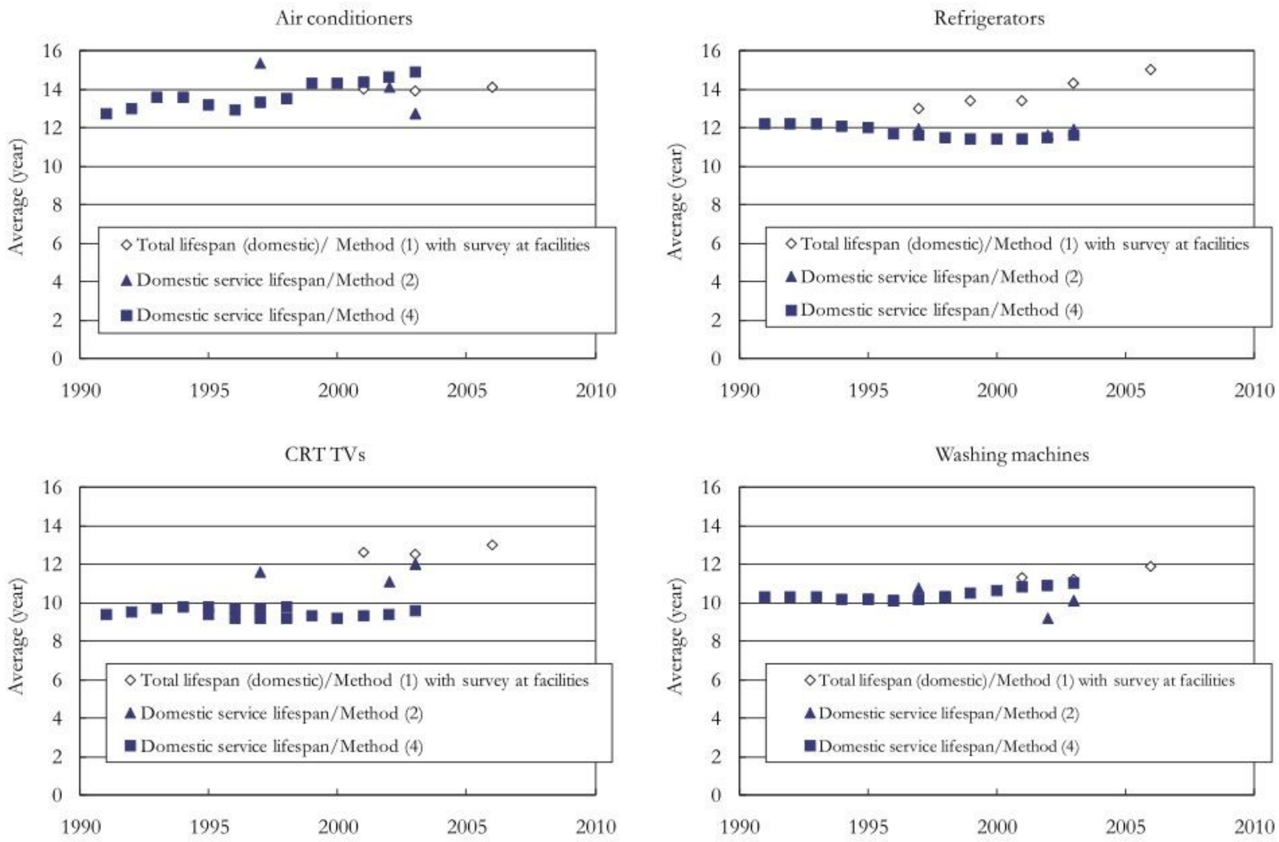
Source: Murakami et al. (2010)

Some of the definitions are more detailed than those used elsewhere in this report (see Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**), and in part a different terminology is chosen (e.g. domestic service span and duration in use). Also, we do not take into account the circulation of materials in the economic sphere, because this is not related to the lifespan of an appliance.

In addition to the classification of the data in accordance with the lifespan terminology, the assumptions made about the distribution of failures are also crucial. As shown above, the results differ depending on whether they are presented in terms of arithmetic means or using a Weibull distribution.

In Oguchi et al. (2010), the results of the LiVES database are presented for air conditioning appliances, refrigerators, televisions, and washing machines. The deviating results in the following Figure 5 are the result of the use of different definitions for the lifespan data (total lifespan, domestic service lifespan), and are also attributable to the fact that the lifespan data were obtained using different methods. In Method 1, the results come from the sorting analysis of waste flows in recycling plants; Method 2 investigates current levels of ownership, and for Method 4 the numbers of appliances in use are estimated and categorised along a timeline. In order to take into account the weaknesses identified in this section regarding the measurement of lifespans, this study draws on data from the Society for Consumer Research (GfK), which also asks about the various reasons for new purchases (see Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**) in order to be able to base further investigations on a reliable basis.

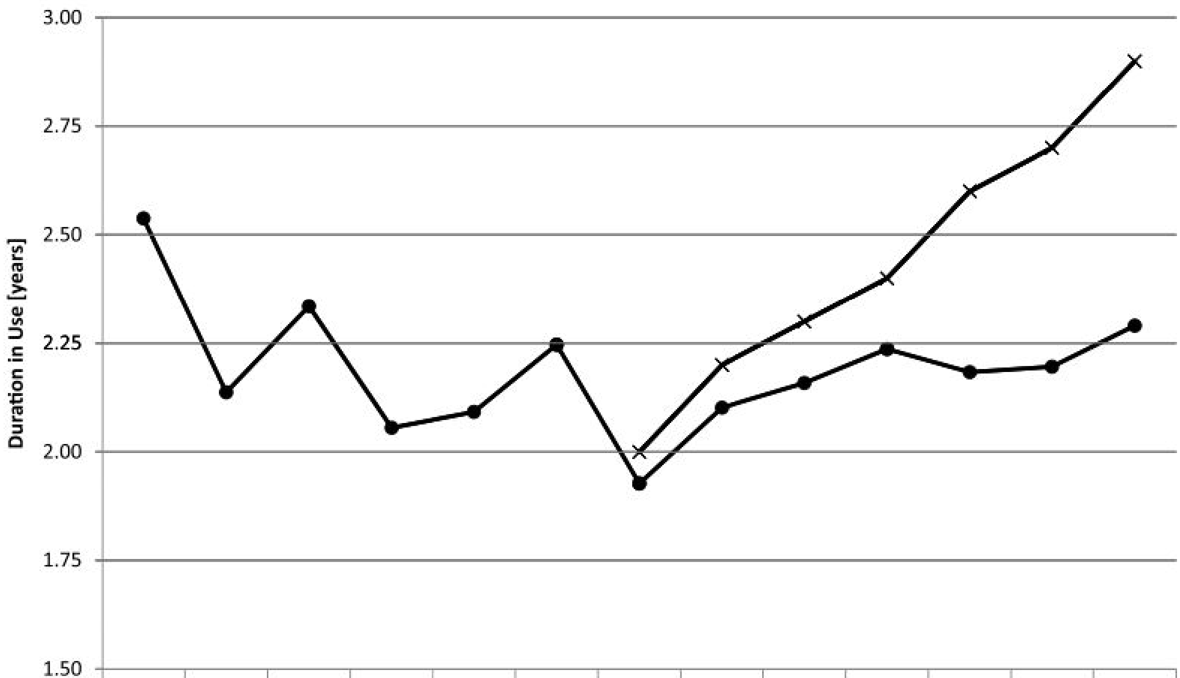
Figure 5 Differences between the average total and domestic service lifespans of household appliances in Japan



Source: Oguchi et al. (2010)

Figure 6 shows the results of two studies on the development of first use duration in Japan. The two studies clearly arrive at different results. Survey 1 is based on the investigations of Murakami et al. (2009), who focussed on the individual use of mobile phones. Survey 2 is based on an investigation of the satisfaction of Japanese consumers in a broader based study of households by the Japanese government (ESRI 2008). The results of the first study are much more precise, which shows how the selection of the survey group can affect the results (Murakami et al. 2010). For this study, it is important to consider the extent to which the framework of a survey can affect the results, and to take into account that there can be no absolute certainty when interpreting these.

Figure 6 Duration of first use of mobile phones in Japan



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Survey 1	2.54	2.14	2.34	2.06	2.09	2.25	1.93	2.10	2.16	2.24	2.18	2.20	2.29
Survey 2							2.0	2.2	2.3	2.4	2.6	2.7	2.9

Survey 1 Survey 2

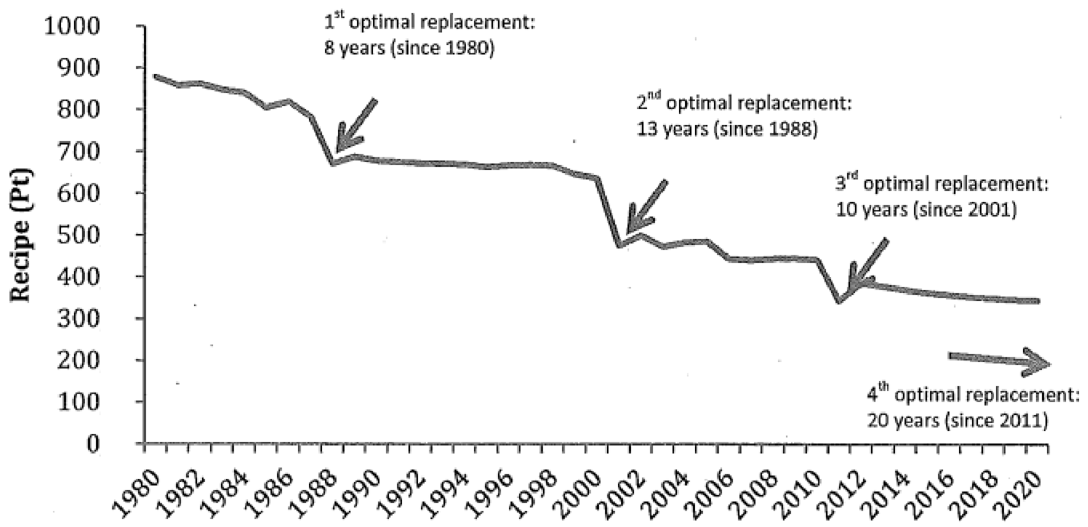
Source: Murakami et al. (2010)

4.6.3 Extended lifespans versus new purchases

An important advantage of a longer lifespan of electrical and electronic appliances is a more intensive use of the resources in the appliance and optimisation with reference to the associated environmental impact. On the other hand, the power consumption is frequently higher than that of more efficient new appliances.

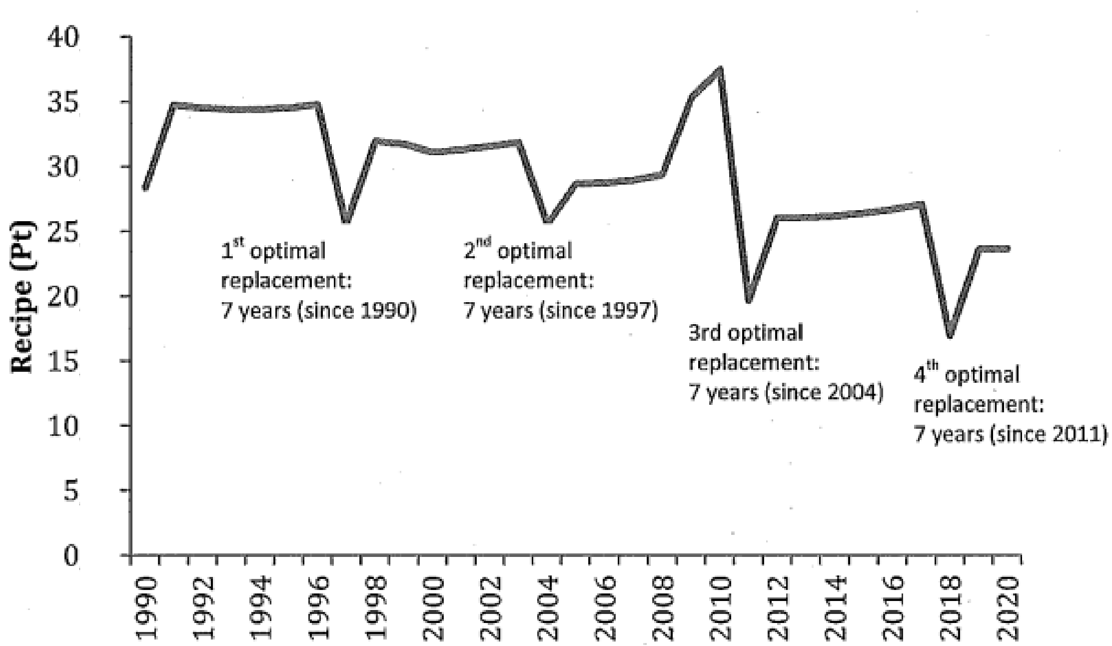
Bakker et al. (2014) investigated various scenarios to assess lifespan extension with reference to the ReCiPe indicator of environmental impact. For laptops and refrigerators, a strategy of extending the lifespan was found to be preferable even though new appliances were more energy-efficient. The comparison is based on a harmonized indicator approach for life cycle impact assessment, taking into consideration human health, biodiversity and resource availability.

Figure 7 **Optimum lifespans for refrigerators/freezers with reference to environmental impact (in ReCiPe points)**



Source: Bakker et al. (2014)

Figure 8 **Optimum lifespans for laptops with regard to environmental impact (in ReCiPe points)**

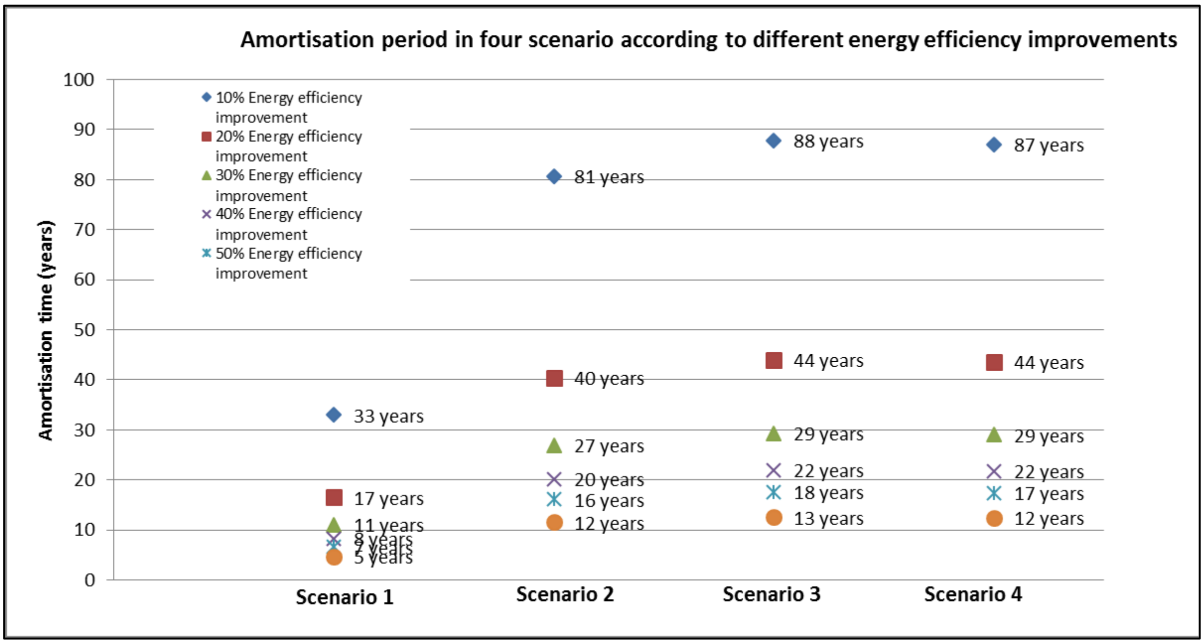


Source: Bakker et al. (2014)

On the basis of their case studies, Bakker et al. (2014) concluded that it would be environmentally beneficial if refrigerators bought in 2011 were used for 20 years rather than only 14 years (Figure 7), and laptops for at least 7 years instead of a current average of 4 years (Figure 8).

Prakash et al. (2012) investigated the environmental amortisation period of laptops with regard to their climate impact. Various energy efficiency potentials for new appliances were assumed and comparisons were made on the basis of scenario calculations. The results with regard to the optimum lifespan are shown in Figure 9 for various energy efficiency increases during the use phase.

Figure 9 Overview of amortisation period as a function of energy efficiency improvement in the use phase, for all scenarios



Source: Prakash et al. (2012)

Depending on the source of the data, the amortisation period is between 33 and 89 years if the new laptop is 10% more energy-efficient in use. In other words, the laptop would have to be used between 33 and 89 years to compensate for the greenhouse gas emissions attributable to the production, distribution, and disposal of the new computer. If the energy efficiency of the new laptop increases by 70%, the amortisation period shortens to values between 6 and 13 years, again depending on the data source (Prakash et al. 2012).

5 Product-specific approaches to estimating lifespan, use times, and residence times

Having considered general methods for the assessment of the lifespan, use time and residence time of appliances, in this chapter product-specific approaches and data surveys are presented:

5.1 Large Household appliances

5.1.1 Generally available data

The estimated lifespans of electrical and electronic equipment vary considerably from country to country. This is due mainly to different surveying and calculation methods, but aspects such as climate conditions also play a role. Furthermore, the data come from different sources and different years.

The following table presents an overview of lifespan data from a variety of studies.

Table 9 Lifespan data for large household appliances

Appliance	Lifespan (years)	Country	Method of data survey	Source
Refrigerators	11 (median)	Spain	Survey of households: Competing risks survival analysis (CR-SA) Telephone interviews	Gutiérrez et al. 2011
Refrigerators	19.8 (mean) 17.7 (median)	USA	Lifespan calculated on the basis of the number of appliances in households and the survival probability	Lutz et al. 2011
Refrigerators	9	China	Annual figures based on official statistical data from China	Yang et al. 2008
Refrigerators	19 (USDOE) 16 (CAMA) 16-20 (SHEU)	Canada	Previous supply data and survival probability” Survey in households	Young 2008
Refrigerators	14.2 (2000) 14.0 (2005)	Nether-lands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Refrigerators	13	China	Based on sales figures for 2005	Eugster et al. 2007
Refrigerators	15	Greece	Survey in households and electrical retailers	Karagiannidis et al. 2005
Freezers	22.4 (mean) 21.2 (median)	USA	Lifespan calculated on the basis of the number of appliances in households and the survival probability	Lutz et al. 2011

Appliance	Lifespan (years)	Country	Method of data survey	Source
Freezers	19 (USDOE) 11 (CAMA) 16-20 (SHEU)	Canada	Previous supply data and survival probability Survey in households	Young 2008
Freezers	10	Greece	Survey in households and electrical retailers	Karagiannidis et al. 2005
Refrigerators Freezers	11	UK	Survey in households	Cooper 2005
Washing machines	9	China	Annual figures based on official statistical data from China	Yang et al. 2008
Washing machines	14 (USDOE) 12 (CAMA) 16-20 (SHEU)	Canada	Supply data, market information and consumer studies Survey in households	Young 2008
Washing machines	12.1 (2000) 11.7 (2005)	Nether-lands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Washing machines	12	China	Based on sales figures for 2005	Eugster et al. 2007
Washing machines	14	Greece	Survey in households and electrical retailers	Karagiannidis et al. 2005
Washing machines Dishwashers Tumble dryers	9	UK	Survey in households	Cooper 2005
Tumble dryers	17 (USDOE) 13 (CAMA) 11-15 (SHEU)	Canada	Previous supply data and survival probability Survey in households	Young 2008
Tumble dryers	14.5 (2000) 14.3 (2005)	Nether-lands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Dishwashers	10.7 (2000) 10.5 (2005)	Nether-lands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Dishwashers	13 (USDOE) 8 (CAMA) 11-15 (SHEU)	Canada	Previous supply data and survival probability Survey in households	Young 2008
Dishwashers	9	Greece	Survey in households and electrical retailers	Karagiannidis et al. 2005
Microwaves	10.9 (2000) 9.4 (2005)	Netherlands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Microwaves	7	UK	Survey in households	Cooper 2005

Appliance	Lifespan (years)	Country	Method of data survey	Source
Microwaves	4.8	Greece	Survey in households and electrical retailers	Karagiannidis et al. 2005
Electric irons	5 (median)	Spain	Survey in households: Competing risks survival analysis (CR-SA) Telephone interviews	Gutiérrez et al. 2011
Kettles, coffee machines	7.0 (2000) 6.4 (2005)	Netherlands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014
Vacuum cleaners	8	UK	Survey in households	Cooper 2005
Vacuum cleaners	8.1 (2000) 8.0 (2005)	Netherlands	Weibull distribution	Wang et al. 2013 Bakker et al. 2014

Gutiérrez et al. (2011) investigated the lifespan of refrigerators and electric irons in Spain in 2007. They were calculating lifespans in order to be able to determine future levels of electrical and electronic waste (environmental aspect) and to be able to adapt production to future demand (economic aspect). The collection of data was followed up by a representative survey of Spanish households. They gathered basic data about the age of the discarded appliances, the reasons for replacing them (failure, functional obsolescence, other reasons), and socio-demographics (number of people in the household, proportion of males, members of household younger than 18 years, cultural status, no. of residents in the local town or city, local climate). Gutiérrez et al. (2011) determined a median lifespan of 11 years for refrigerators, but this was significantly dependent on the climate. In climate zones with high temperature fluctuations, the lifespan was short. Whereas some refrigerators were in use for more than 15 years, most electric irons were replaced within 5 years. The main reason for the new purchase for all appliances was that the old appliance was broken, the second most frequent reason was the functional obsolescence, and only rarely was the replacement due to other reasons (Gutiérrez et al. 2011).

Lutz et al. (2011) investigated the lifespan of refrigerators and freezers in the USA. The calculations were based on all sales data from the post decades and reports of households about the approximate date of the appliances that were still in use. For example, if 100,000 units were sold between 1980 and 1990, and a survey in 2000 found that 80,000 units were between 10 and 20 years old, it could be concluded that 80% of the appliances were still in use and that 20% had been disposed of. For refrigerators, this gave a mean lifespan of 18.5 years, and for freezers a lifespan of some 22 years. Though this method of calculation is not very precise, it does clearly show that the actual lifespan is much longer than the expected lifespan (Lutz et al. 2011).

Eugster et al. (2007) and Yang et al. (2008) studied the lifespans of electrical appliances in China, but they came to very different conclusions. Eugster et al. (2007) calculated the lifespans using data for all imports, exports and sales for the period 1989–2006. For refrigerators, they calculated a mean lifespan of 13 years and for washing machines a mean lifespan of 12 years. In contrast, the calculations of Yang et al. (2008) were based on available statistical data collected using a questionnaire. On this basis, they calculated a much shorter lifespan for refrigerators and washing machines of only some 9 years in each case (Eugster et al. 2007; Yang et al. 2008).

Young et al. (2008) investigated the lifespan of electrical appliances in Canada. They drew on the Survey of Household Energy Use (SHEU)-2003, carried out by the Canadian Office of Energy Efficiency (OEE) and calculated the exchange rate of large household appliances. The survey included various questions about product age ranges of large household appliances when they were replaced (refrigerators, freezers, dishwashers, washing machines, tumble dryers). The results were used to determine whether the age distributions from earlier studies could be transferred to Canada. In addition to the age of the appliances, the reasons for their replacement were also investigated. Important factors were an improved energy efficiency and the better performance of the new appliance. It was also found that the higher the disposable income of a household, the more likely it was that a functioning appliance would be replaced prematurely, mostly for a better model (Young et al. 2008).

The age distributions of large household appliances used in most studies for the USA are based on the data from the US Department of Energy (USDOE). Various methods are used to determine the mean lifespan. Sales data was analysed for refrigerators and freezers (1995), whereas in the case of washing machines information was evaluated from a wider range of sources (sales data, market information and “Clothes Washer Consumer Analysis” 2000) (Young et al. 2008).

Data about the lifespan of large household appliances in Canada was previously generated by the Canadian Appliance Manufacturers Association (CAMA). However, the calculations only covered the period of first use, without taking into account any repairs and second use. The CAMA data are based on a survey of the age of appliances when they were replaced (Young et al. 2008).

Young et al. (2008) compared the results of SHEU-2003 with the data of USDOE and CAMA. They determined an average lifespan for dishwashers and tumble dryers of 11–15 years and a lifespan for refrigerators, freezers and washing machines of 16–20 years. For refrigerators, freezers and dishwashers, the data match those for the USDOE. The average age for washing machines was two years higher, and for tumble dryers was two years lower. With the exception of tumble dryers, the average lifespan for all types of appliance were higher than the CAMA values, i.e. if no allowances were made for second use then the lifespan was considerably underestimated. According to SHEU-2003, dishwashers are the appliances most likely to be replaced within5 years, whereas refrigerators and freezers can well be in use for more than 20 years.

Wang et al. (2013) evaluated two very extensive consumer surveys from 2007 and 2009 to determine the average lifespans of household appliances in the Netherlands. Data was collected about the age of appliances, frequency of use, as well as details about the purchase and the disposal of appliances. The results were compared with data from Dutch recycling and disposal operators. A Weibull distribution was produced with which the average lifespan of the appliances could be determined for the years 2000 and 2005. For all the household appliances investigated, it was found that the lifespan declined over this period (Wang et al. 2013).

Cooper (2005) evaluated the E-SCOPE survey for the years 1998/1999 in order to calculate the lifespans of household appliances in Great Britain. This survey of 800 households included questions about life expectancy, the age and condition of appliances on disposal, factors which deter consumers from buying more durable products, and attitudes and behaviour regarding the repair of all categories of household appliances. The survey found that appliances were replaced after a mean lifespan of 4 to 12 years, depending on the type of appliance. Most of the appliances still in use in the households were relatively new. More than half of all appliances (57%) were less than 5 years old, and 88% were less than 10 years old. Most of the consumers interviewed in the study said that they felt that the lifespan of household appliances had become shorter over time, but this was not quantified (Cooper 2005).

5.1.2 GfK survey

The following results are based on market studies of the GfK Society for Consumer Research on the length of use of large household appliances in Germany[21]. Consumers responded in writing to questions about when and why they purchased new appliances, and how long they had used the replaced appliances. To register purchases of large household appliances (LHA) in the period January 2012 to July 2013, 15,000 participants from the GfK Consumer panel were surveyed in August 2013. The following questions were asked:

- Have you purchased a new large household appliance in the years 2012/2013?
- What was the main reason for the purchase?
    1. This type of appliance was not previously available
    2. Wanted an additional appliance
    3. The old appliance was broken
    4. The old appliance was unreliable /faulty
    5. The old appliance still works, but I wanted a better one
- If the purchased appliance has replaced another one or has been bought as an additional appliance, please give the age of the replaced or existing appliance.

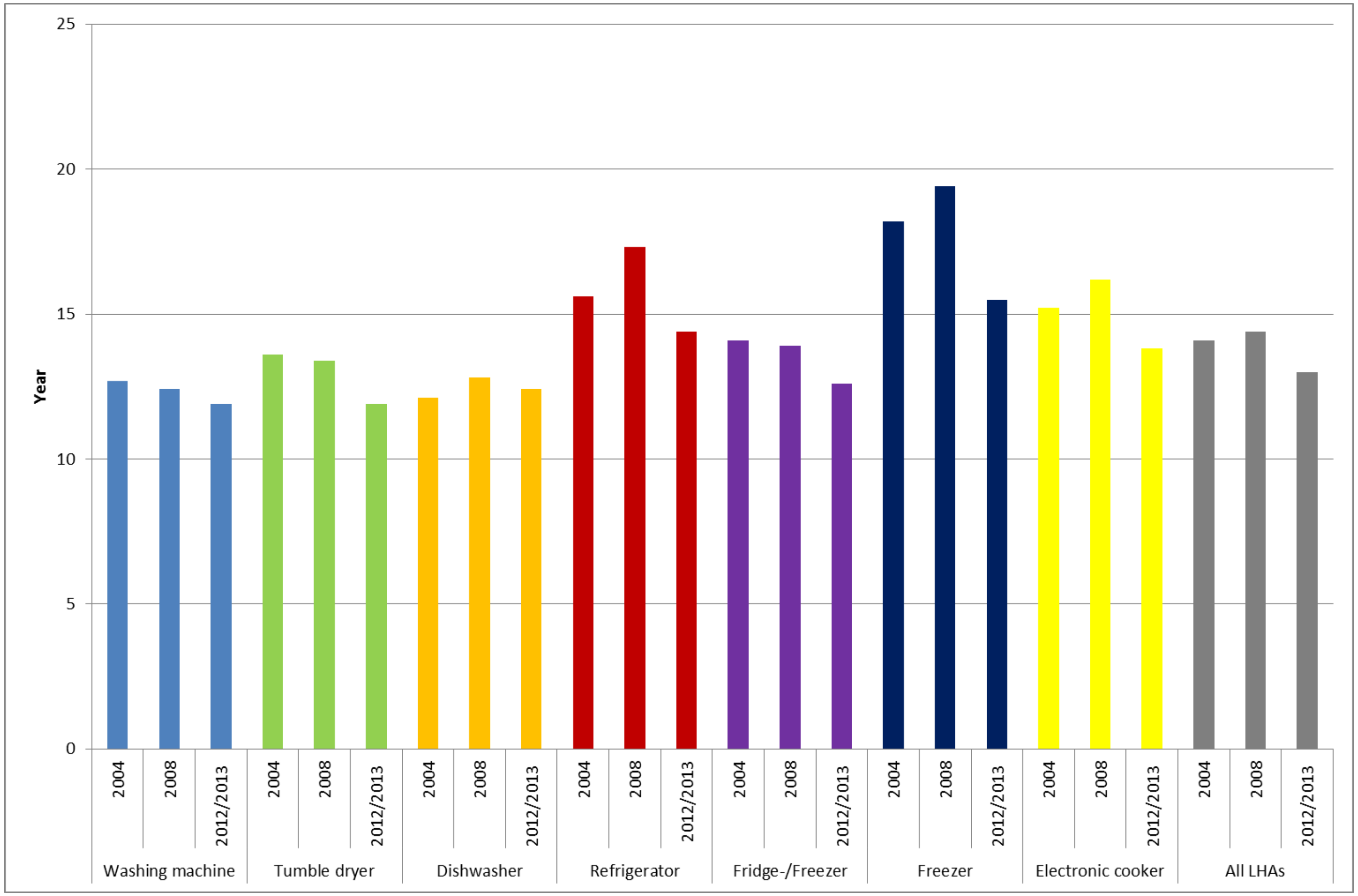
The study asked about the first use of the appliance, which should not be confused with the technical lifespan. Second uses of appliances were not registered. After excluding invalid responses, date remained for n = 7146 purchased appliances. The responses were frequency weighted in order to achieve representative results. These were then compared with the results of similar GfK surveys from the years 2004 and 2008[22]. However, since the individual sample sizes for 2004 and 2008 were much smaller than for 2012, only mean data for all large household appliances were felt to be sufficiently reliable.

The average first use of large household appliances declined slightly between 2004 and 2012 from 14.1 years to 13.0 years. The trend towards shorter periods of use for appliances can be observed independent of the reason for purchase (Figure 10). This is most noticeable for the average first use duration of freezers and tumble dryers, which declined from 18.2 to 15.5 years and 13.6 to 11.9 years, respectively. The shortest first use in households was found for washing machines und tumble dryers - namely 12 years (2012). The first use of dishwashers was also 12 years, showing little change over the years. Freezers were frequently used the longest in comparison with other household appliances, and they had a mean first use of 16 years (2012).

[21] The GfK consumer survey in 2013 was commissioned by the German Electrical and Electronic Manufacturers' Association (ZVEI). Permission has kindly been granted to use and publish the GfK data in this study.

[22] Monthly registration of purchases of large household appliances in the 20,000 GfK Consumer Panel

Figure 10 Development of the mean first use duration of large household appliances in Germany (2004, 2008, 2012/2013)[23]



Source: Our presentation; based on GfK data (2004: n= 2712; 2008: n=3380; 2012: n=5664 for all LHAs; for product groups, “n” between 363 and 1600 in 2012)

[23] In part very low individual numbers of cases for 2004 and 2008; only mean data for all large household appliances (LHA) are sufficiently reliable.

Considering the period of first use in combination with the reason for a new purchase (**Fehler! Verweisquelle konnte nicht gefunden werden.**), the survey showed that in 2012/2013 freezers were being replaced by a better one up to 3 years earlier, after a first use period of 17 years, even though they were still working. This is a clear reduction, and considering this reason for replacement it is higher than for the other types of appliance. **Fehler! Verweisquelle konnte nicht gefunden werden.** also shows that all large household appliances (excepting dishwashers) in 2012/2013 were replaced somewhat earlier because of a defect ('The old appliance broke') than in 2004. For example, washing machines were being replaced in 2012/2013 0.9 years earlier due to a defect than in 2004, freezers 3.1 years earlier, and tumble dryers 2.8 years earlier.

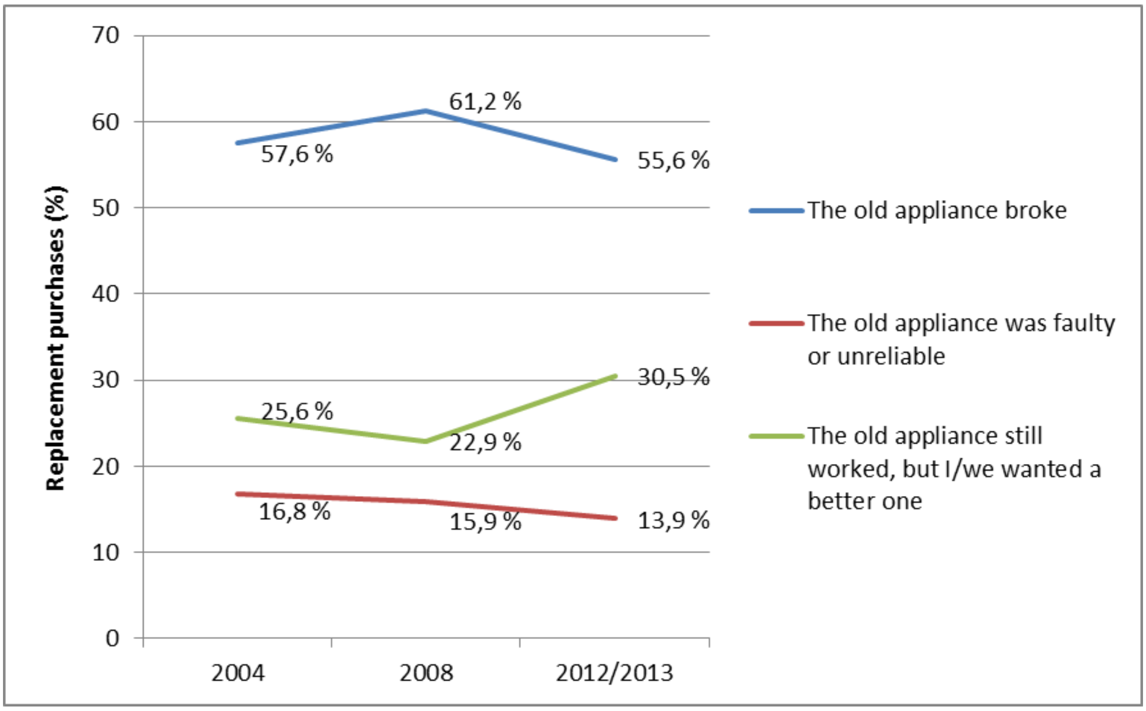
Table 10 Mean first use of large household appliances

Appliance	Survey period	Mean first use in years depending on reason for replacement			
		All reasons (the old appliance broke / was faulty or unreliable / wanted a better appliance)	The old appliance broke	The old appliance was faulty / unreliable	The old appliance still worked, but I/we wanted a better one
All LHAs	2004 (n= 2712)	14.1	13.5	14.6	15.0
	2008 (n= 3380)	14.4	13.9	13.9	16.2
	2012/2013 (n=5664)	13.0	12.5	13.8	13.6
Washing machines	2004 (n=882)	12.7	12.5	13.2	13.1
	2008 (n=1077)	12.4	12.6	10.8	13.3
	2012/2013 (n=1600)	11.9	11.6	13.2	13.2
Tumble dryers	2004 (n=181)	13.6	13.1	15.1	14.1
	2008 (n=257)	13.4	13.0	15.3	13.9
	2012/2013 (n=353)	11.9	11.3	14.1	12.5
Dish washers	2004 (n=394)	12.1	12.3	11.9	11.7
	2008 (n=564)	12.8	12.8	11.8	13.8
	2012/2013 (n=960)	12.4	12.5	13.1	11.4
Refrigeration appliances	2004 (n=567)	15.0	14.6	16.0	15.1
	2008 (n=689)	15.7	16.0	15.4	15.4
	2012/2013 (n=1381)	13.5	13.6	13.5	13.5
	2004 (n=338)	15.6	15.1	16.7	15.9

Appliance	Survey period	Mean first use in years depending on reason for replacement			
		All reasons (the old appliance broke / was faulty or unreliable / wanted a better appliance)	The old appliance broke	The old appliance was faulty / unreliable	The old appliance still worked, but I/we wanted a better one
of which - refrigerators	2008 (n=316)	17.3	17.5	17.3	17.1
	2012/2013 (n=704)	14.4	14.0	15.1	14.7
- fridge-freezers	2004 (n=229)	14.1	13.7	14.9	14.1
	2008 (n=369)	13.9	13.8	13.8	14.0
	2012/2013 (n=677)	12.6	13.1	11.9	12.5
- freezers	2004 (n=236)	18.2	16.1	18.5	20.4
	2008 (n=351)	19.4	17.9	17.1	21.0
	2012/2013 (n=419)	15.5	13.0	16.0	17.0
Electric cookers	2004 (n=452)	15.2	16.7	15.1	14.2
	2008 (n=442)	16.2	16.1	16.7	16.0
	2012/2013 (n=951)	13.8	14.1	14.3	13.3

For all large types of household appliances, there has been a slight decline in replacement purchases due to a defect between 2004 and 2012, but this is not always the main reason for the replacement. The proportion of replacement purchases of large household appliances because of a defect was 57.6% in 2004 and 55.6% in 2012. On the other hand, nearly a third of the large household appliances replaced in 2012/3 were still in working order. In 2012/2013, appliances replaced because the owner(s) wanted to have a better appliance although the old one was still in working order accounted for 30.5% of all replacement purchases (Figure 11).

Figure 11 Reasons for replacing large household appliances, irrespective of age



Source: Our presentation; based on GfK data (2004: n= 2712; 2008: n=3380; 2012: n=5664 for all LHAs)

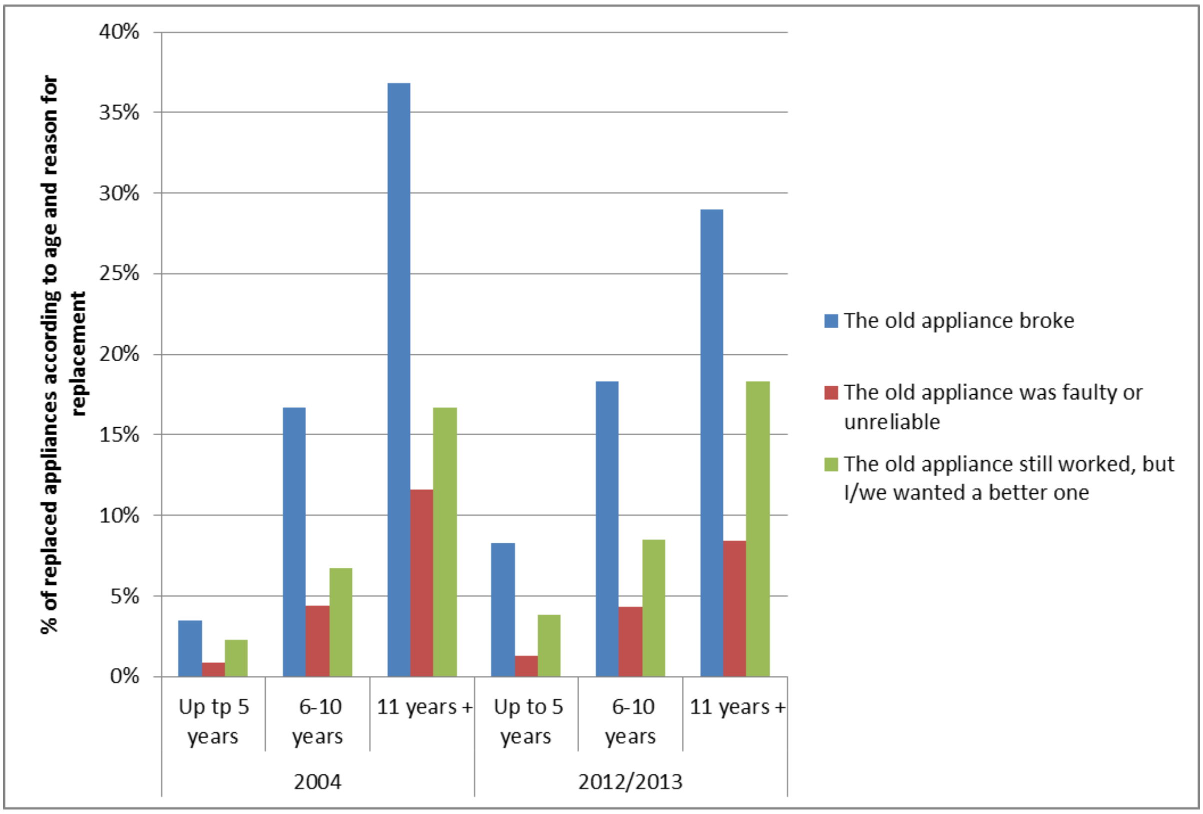
There have been noticeably more purchases to replace appliances that are only up to five years old. Between 2004 and 2012/2013, such replacement purchases increased from 7% to 13% of all replacement purchases irrespective of the reason for replacement (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 11 Percentage of replaced appliances in various age categories, irrespective of reason for replacement and type of appliance

First use of replaced appliance	Survey period		
	2004	2008	2012/2013
	% of replacement purchases		
Up to 5 years	7	8	13
6-10 years	28	27	31
11 years or more	65	65	56

This change can be attributed to the increase in the proportion of large household appliances in the category up to 5 years old that were replaced due to a defect. Between 2004 and 2012, the proportion of all large household appliances purchases that were made to replace defective appliances that were up to 5 years old increased from 3.5% to 8.3% (Figure 12). In the same period, the proportion of large household appliances purchases made to replace appliances up to 5 years old that still worked because of the wish to have a better one increased from 2.3% to 3.8% of all replacement purchases (Figure 12).

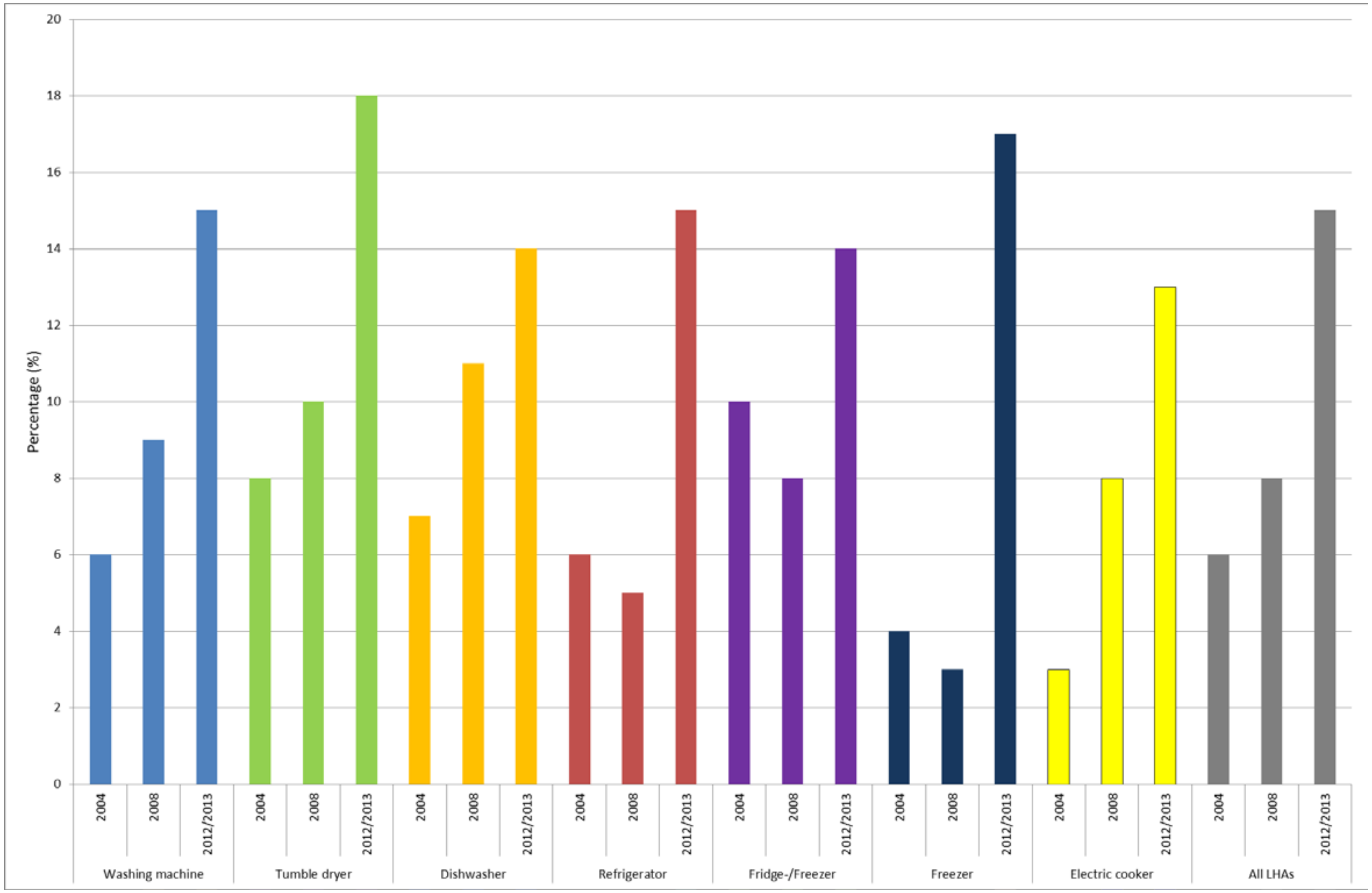
Figure 12 Percentages of replaced large household appliances according to age and reason for replacement



Source: Our presentation; based on GfK data (2004: n= 2712; 2012: n=5664 for all LHAs)

In the category "the old appliance broke", there was an overall increase of approximately 10% between 2004 and 2012 (Figure 13). Of the old appliances replaced because they were broken, 18% of tumble dryers and 17% of freezers were only up to 5 years old. Both types of appliance showed the greatest increase in replacement rates between 2004 and 2012. The lowest replacement rate for very young appliances in 2012 was for electric cookers. All other types of appliances such as washing machines, refrigerators and dishwashers had replacements rates in 2012 of about 15% for appliances that had been used for less than 5 years.

Figure 13 Percentage of large household appliances up to five years old of all replacement purchases in the category "the old appliance broke"[24]

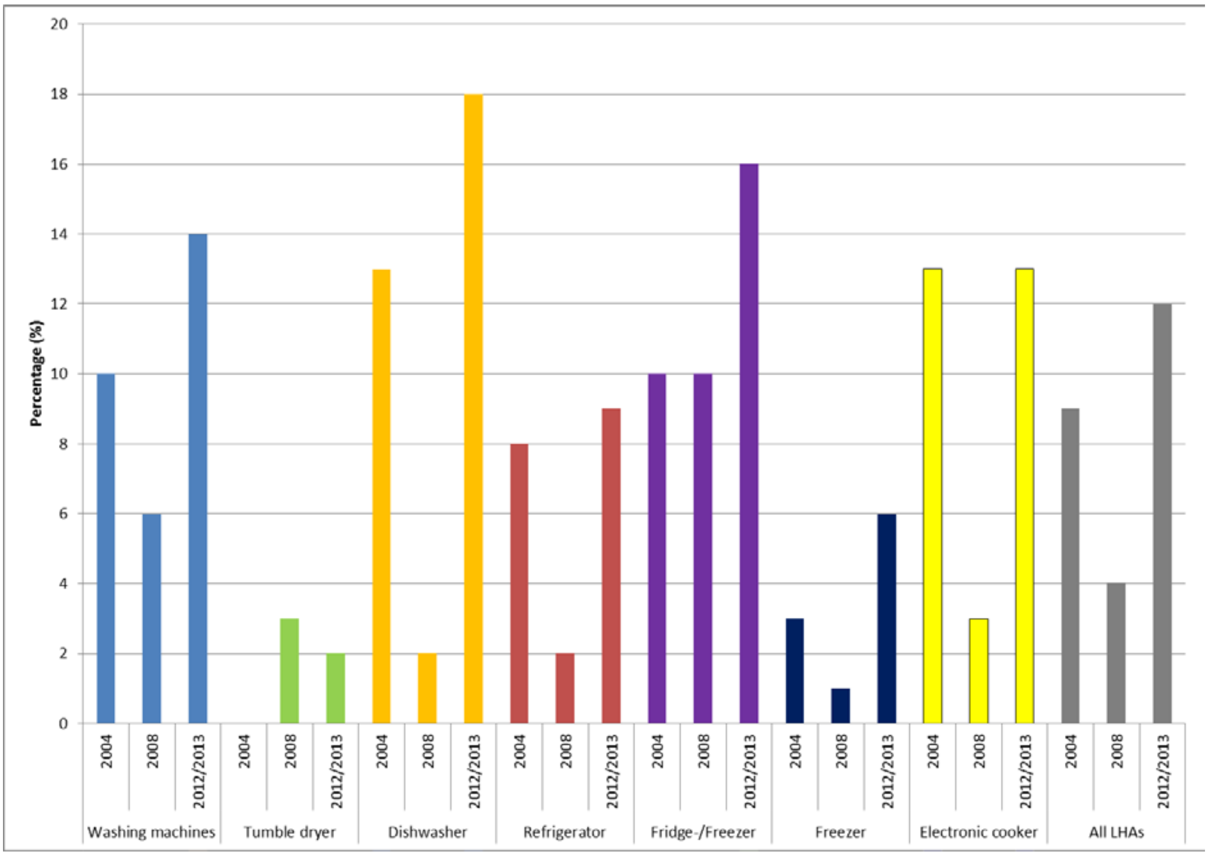


Source: Our presentation; based on GfK data (2004: n= 2712; 2008: n=3380; 2012: n=5664 for all LHAs)

[24] Some very small sample sizes for 2004 and 2008; only data for all LHAs is statistically reliable

Figure 14 shows that a large proportion of consumers replaced functioning appliances relatively quickly because they wanted a better one. In 2012, 14% of replaced washing machines in the category "The old appliance still worked, but I/we wanted a better one" were only up to 5 years old. The corresponding figure for dishwashers was 18% and for fridge/freezers 16%. For all large household appliance, the proportion of functioning replaced appliances that were up to five years old increased from 9% in 2004 to 12% in 2012/2013.

Figure 14 Percentage of replaced large household appliances aged up to five years in the category "The old appliance still worked, but I/we wanted a better one"[25]

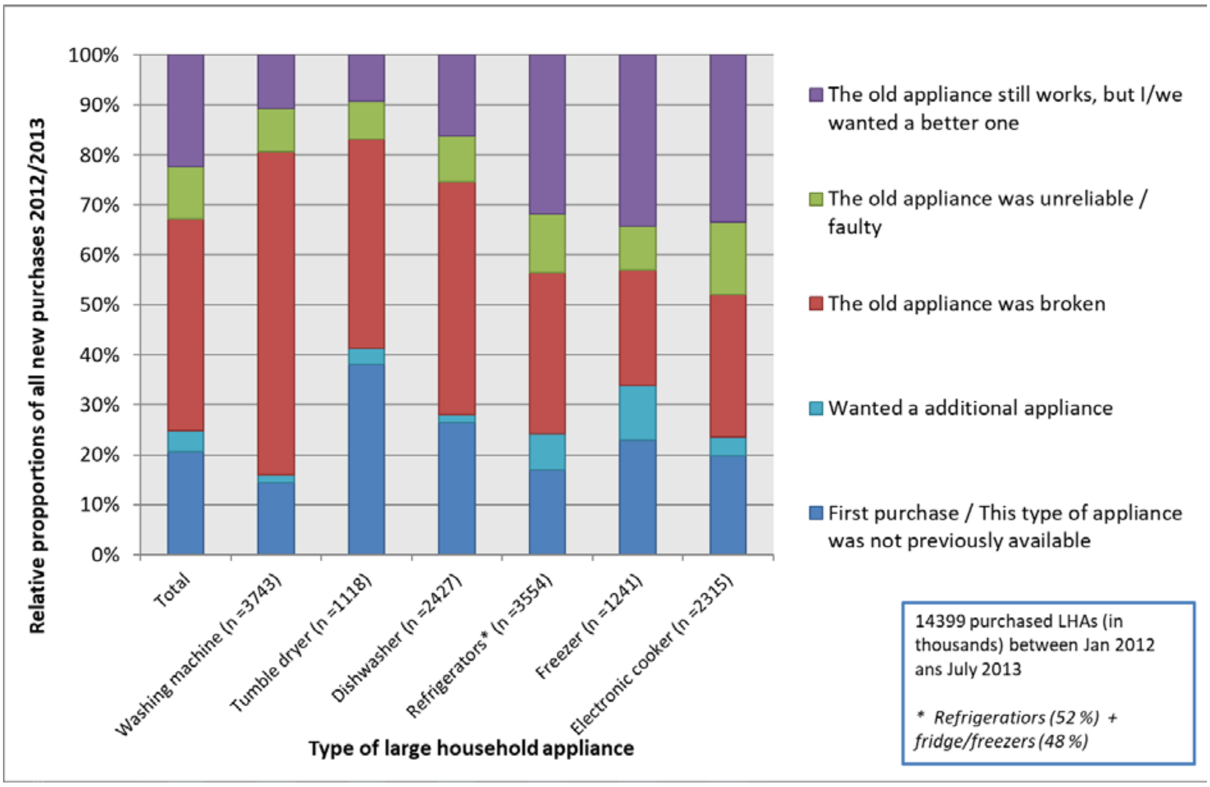


Source: Our presentation; based on GfK data (2004: n= 2712; 2008: n=3380; 2012: n=5664 for all LHAs)

In 2012/2013, washing machines (n = 3743) and refrigeration appliances (n = 3554) made up the largest shares of all new purchases (n = 14399). The main reason for purchasing a washing machine was because the previous appliance broke (Figure 15). This was also the main reason given for purchasing a new dishwasher. In contrast, more than 30% of all new electric cookers were purchased mainly to have a better appliance, with almost the same results for refrigeration appliances and freezers. Freezers and tumble dryers each accounted for only about 10% of all new purchases, but it is noticeable that in the case of tumble dryers nearly 40% were first-time purchases.

[25] Some very small sample sizes for 2004 and 2008; only data for all LHAs are statistically reliable

Figure 15 New and replacement purchases of large household appliances and reason for purchase (2012)



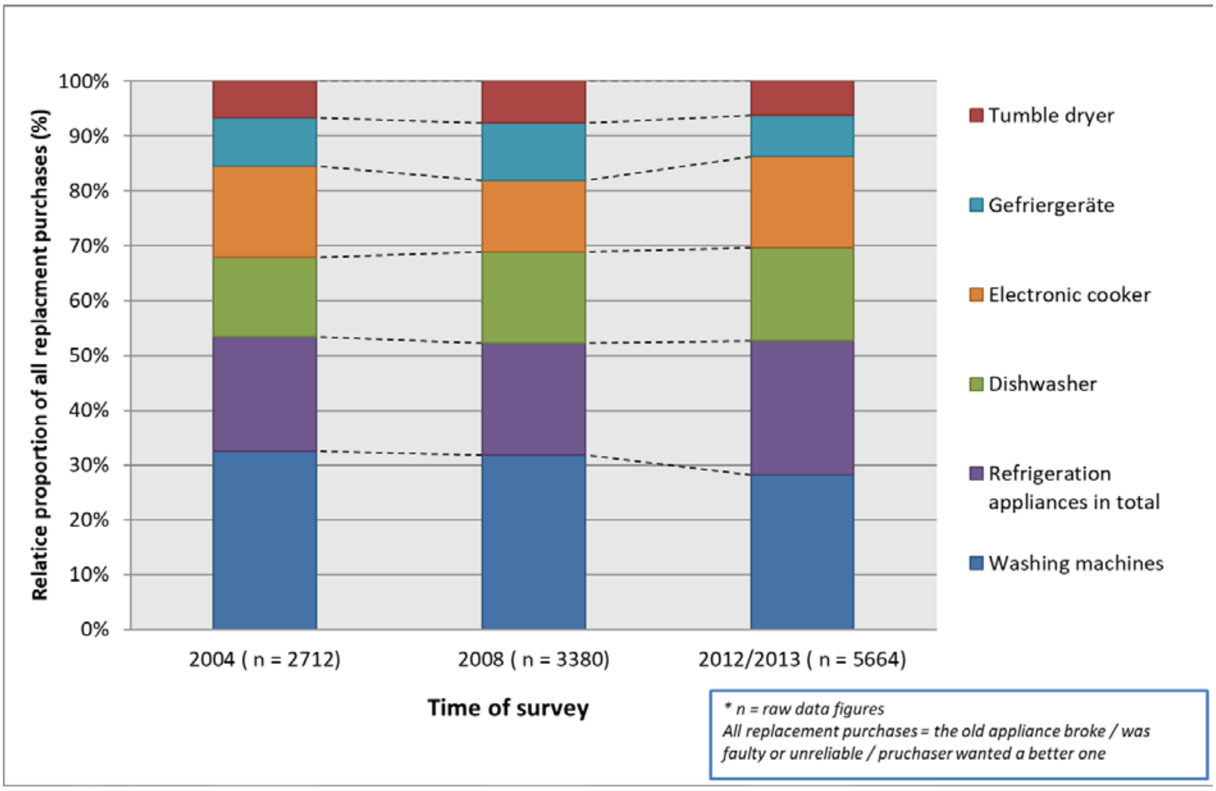
Source: Our presentation; based on GfK data

Comparable surveys were carried out in 2004 and 2008, registering monthly purchases of large household appliances in the 20,000 GfK Consumer panel. This allowed conclusions to be drawn about trends and comparisons made about the length of use and the reasons for purchases. However, first-time purchases were not registered in 2004 and 2008, so that here no comparisons are possible.

From 2004 to 2012, there was a slight decline in replacement purchases for washing machines (Figure 16). Replacement purchases were defined as all purchases made because the existing appliance was broken, faulty or unreliable, or because the purchaser wanted a better appliance. In 2012, increased numbers of washing machines were replaced, and also refrigeration appliances [26]. The proportion of refrigerators in all replacement purchases of refrigeration appliances declined over the years by 10%, whereas fridge-freezers accounted for nearly 50% of replacement refrigeration appliances in 2012 (Figure 17).

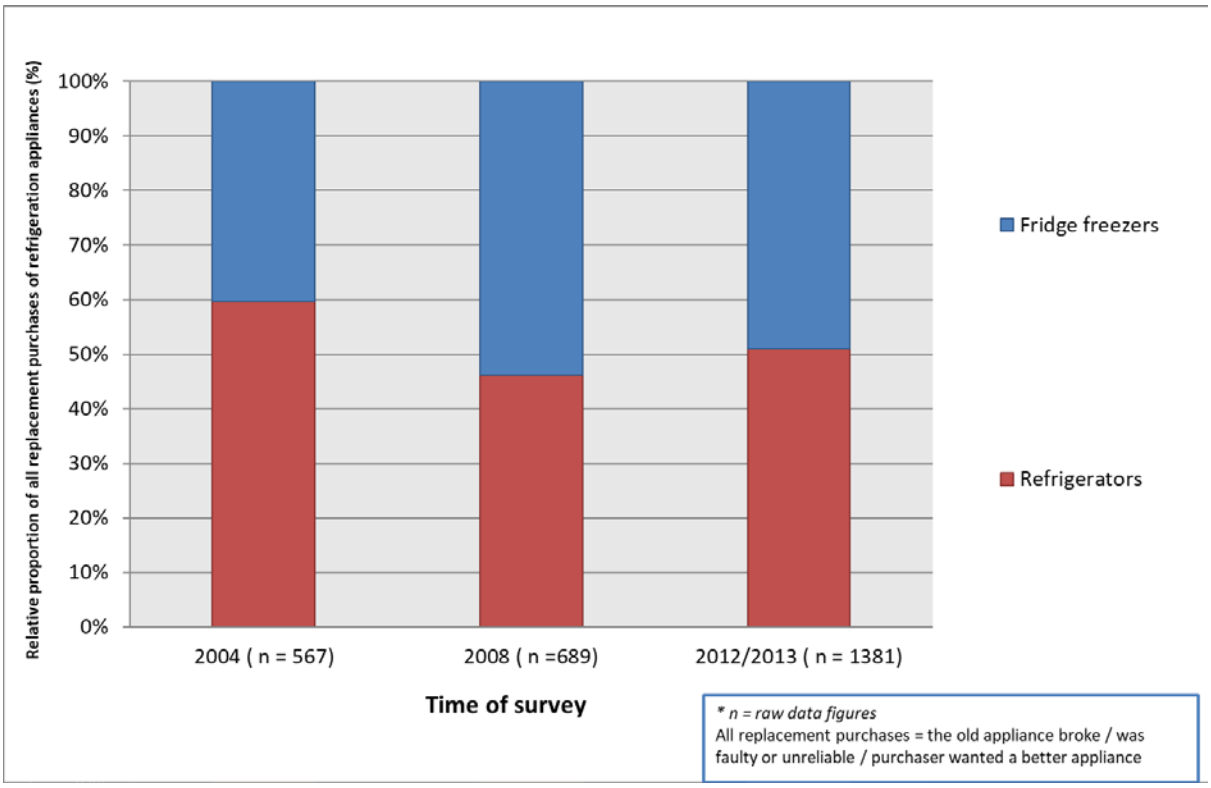
[26] Refrigeration appliances is used as a general term for refrigerators and fridge-freezers

Figure 16 Percentages of all replacement purchases according to types of appliance



Source: Our presentation; based on GfK data

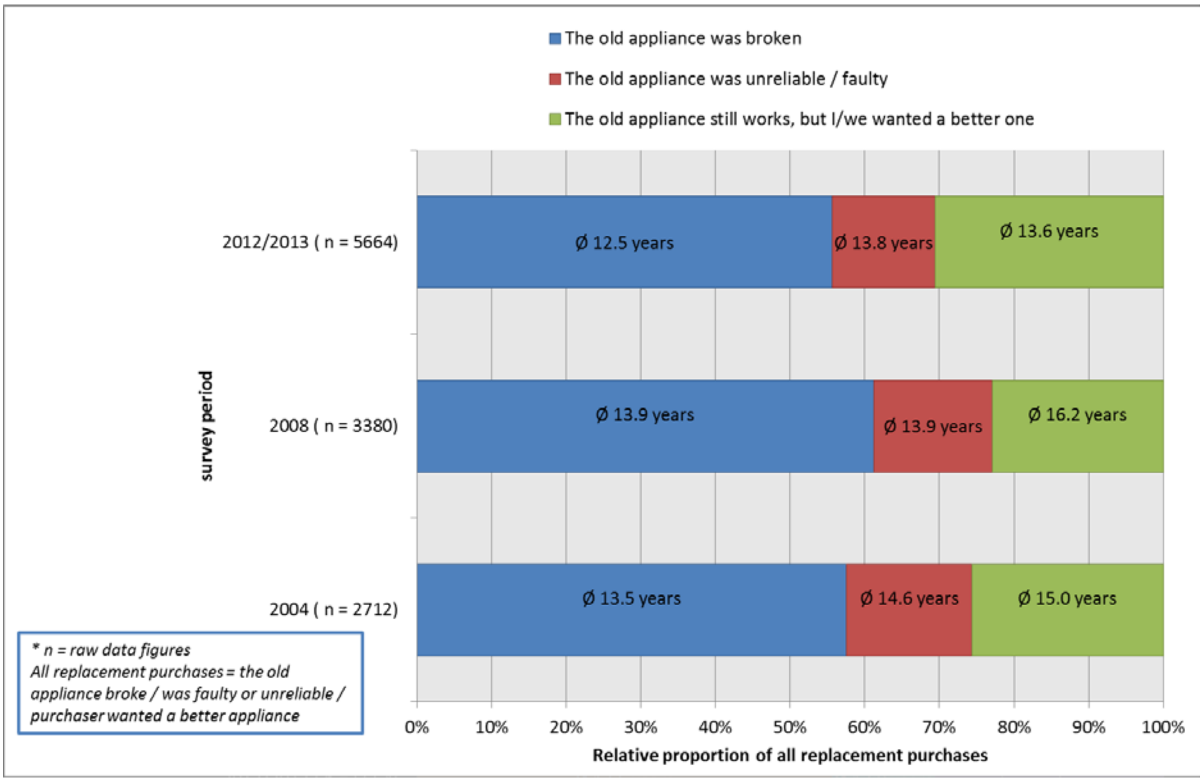
Figure 17 Proportion of refrigeration appliance types for all replacement refrigeration appliances



Source: Our presentation; based on GfK data

Comparing only the replacement purchases in the relevant periods (Figure 18), it is noticeable that the average duration of the first use of appliances replaced due to defects decreased from 13.5 years in 2004 to 12.5 years in 2012 (Figure 18). The proportion of faulty or unreliable replaced appliances decreased slightly to 14% in 2012. However, for this category the average first use period of 13.8 years (2012) is slightly higher than for replaced broken appliances. It is noticeable that in 2012/2013 appliances were increasingly being replaced by a better one even though they were still working, accounting for nearly a third of all replacement purchases. It is also noticeable that overall the average first use period decreased over the years.

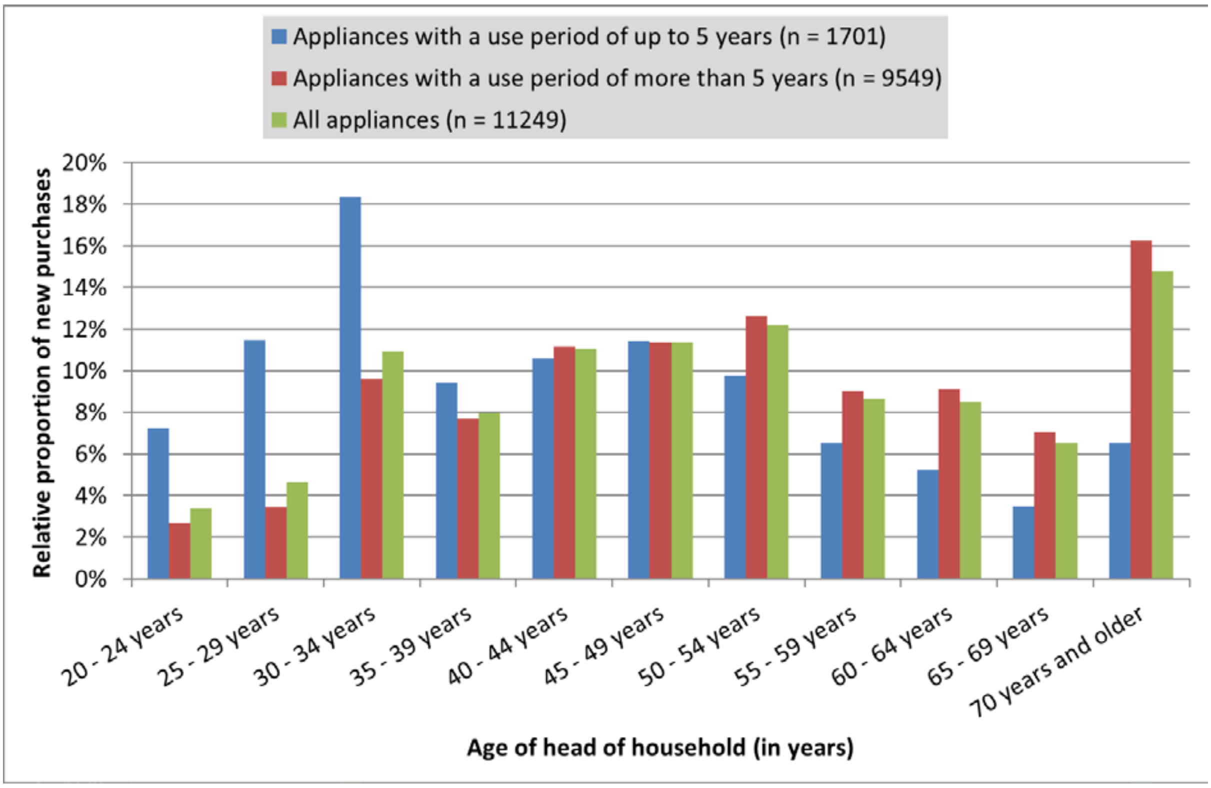
Figure 18 Replacement purchases according to the reason for the purchase and the average first-use period of the appliance



Source: Our presentation; based on GfK data

A closer analysis of the socio-economic characteristics (where data was available) shows that in particular the purchasers under the age of 35 years had a much higher rate of replacement of appliances with a first-use period of up to 5 years (Figure 19).

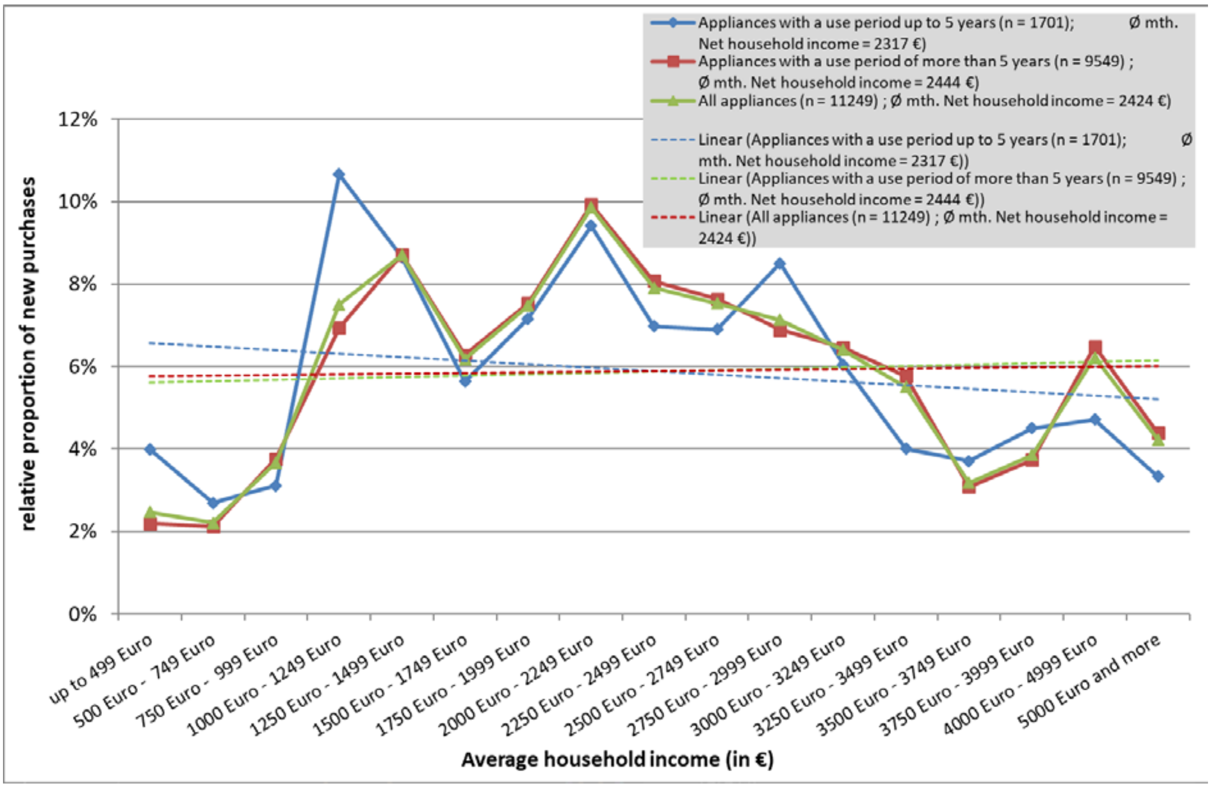
Figure 19 First use period of large household appliances and age of head of household (2012/2013)



Source: Our presentation; based on GfK data

Figure 20 shows that households that replace their appliance after a short first-use period have a lower average income than households who use their appliance for a longer period (in contrast to Young et al. 2008). However, this difference is not very marked, and could be attributable to age-related income differences.

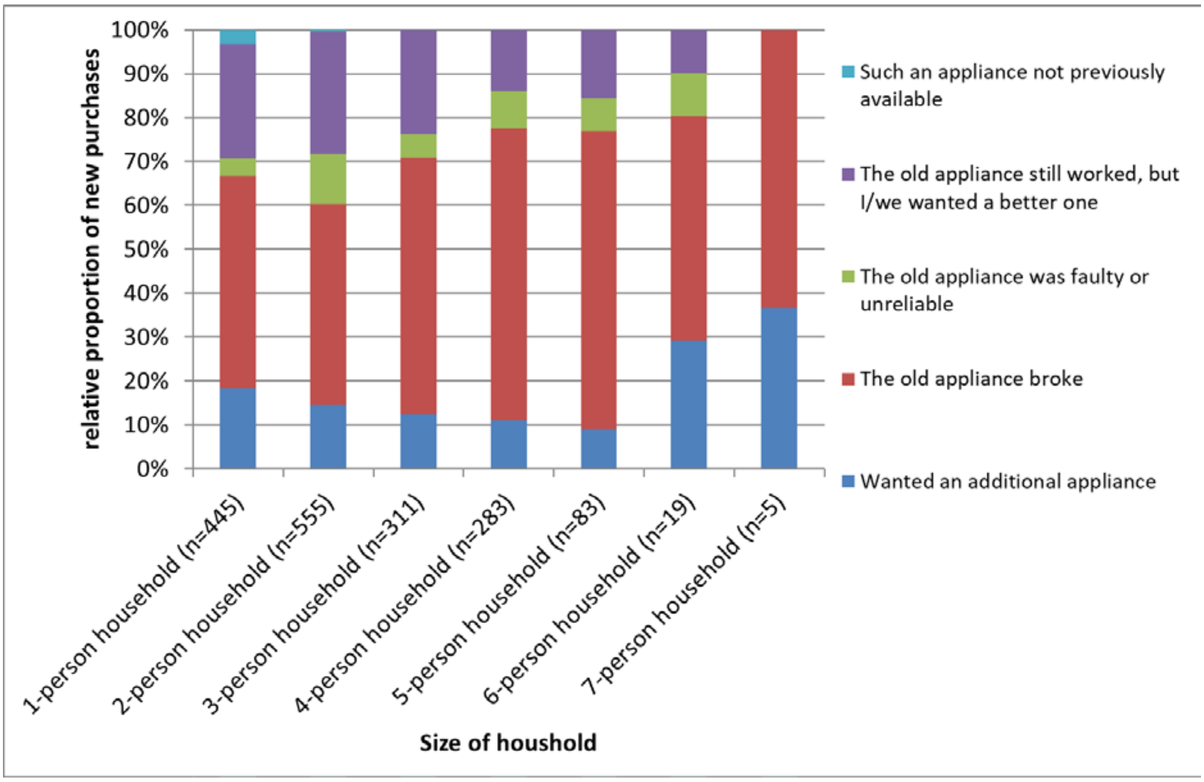
Figure 20 Household net income and period of use of large household appliances (2012/2013)



Source: Our presentation; based on GfK data

Considering the survey results for 2012/2013 concerning household size, it is noticeable that 3- to 5-person households replace broken appliances more frequently within a first-use period of up to five years, which could indicate more frequent use (Figure 21). For one- and two-person households, a frequent reason is the wish for a better or an additional appliance.

Figure 21 Main reason for replacing appliance with a use period of up to five years depending on size of household



Source: Our presentation; based on GfK data

Irrespective of the age of the appliances, the surveys showed a slight decline in the proportion of replacements due to a defect or an unreliable/faulty appliance for refrigeration appliances, freezers, tumble dryers and dishwashers between 2004 and 2013 (**Fehler! Verweisquelle konnte nicht gefunden werden.**). However, there was an increase in the proportion of replacements because the purchaser wanted a better appliance, in particular in the case of freezers, electric dryers, dishwashers, and refrigeration appliances. The replacement rates increased by 5% to 10%. More of half of all freezers are now replaced due to the wish for a better appliance. And the proportion of refrigeration appliances and electric cookers is very high, at more than 40% of replacement purchases. For washing machines, tumble dryers und dishwashers the most frequent reason given for replacement purchases is that “the old appliance broke”.

Table 12 Reasons for replacing large household appliances

Appliance	Survey period	No.	Main reason for purchase		
			The old appliance broke	The old appliance was faulty/unreliable	The old appliance still worked, but I/we wanted a better one
Washing machines	2004	882	74%	16%	10%
	2008	1077	75%	15%	10%
	2012/2013	1600	76%	11%	13%

Appliance	Survey period	No.	Main reason for purchase		
			The old appliance broke	The old appliance was faulty/unreliable	The old appliance still worked, but I/we wanted a better one
Tumble dryers	2004	181	71%	17%	12%
	2008	257	75%	9%	16%
	2012/2013	353	68%	13%	19%
Dishwashers	2004	394	68%	14%	18%
	2008	564	74%	15%	11%
	2012/2013	960	64%	12%	24%
All refrigeration appliances	2004	567	46%	16%	38%
	2008	689	47%	17%	35%
	2012/2013	1381	42%	15%	43%
Freezers	2004	236	42%	15%	42%
	2008	351	38%	15%	48%
	2012/2013	419	36%	13%	52%
Electric cookers	2004	452	33%	24%	43%
	2008	442	45%	22%	33%
	2012/2013	951	37%	20%	43%

Summary

According to the latest figures, some 70% of all replacement large household appliances are purchased because of a fault or defect in the existing appliance. This is the main reason given for replacing washing machines, tumble dryers, and dishwashers. Nearly a third of all replaced large appliances are still working, with considerably larger proportions for refrigeration appliances and electric cookers in particular. Nearly half of all electric cookers, refrigeration appliances and freezers were replaced because of the wish to have a 'better' appliance.

In 2012, washing machines accounted for the largest share of replacement purchases, followed by refrigeration appliances and dishwashers. The most first purchases were in the group of tumble dryers. One third of 2- or 3-person households buy a tumble dryers as their first appliance. Single households are the largest group of first-time purchasers of washing machines.

According to the GfK survey data, the average duration of first use of appliances that are replaced due to a defect, a fault or unreliability, or the wish for a better appliance fell slightly from 14.1 years (2004) to 13.0 years in 2012/2013. The average age of 'broken appliances' in 2012/2013 was 12.5 years, compared with 13.9 years in 2004 and 13.5 years in 2008. There has been a noticeable fall in the first-use period for freezers, from 16 years in 2004 to 13 years in 2012. Also electric cookers are now replaced because they are broken 3 years earlier on average, namely after 14 years. Consumers replace broken tumble dryers already after 11 years.

Dishwashers show the least change in their use duration, irrespective of the main reason for replacing them.

There has been a marked increase in replacement purchases for appliances that are up to 5 years old. Whereas in 2004 only 7% of replacement purchases for large household appliances that were up to 5 years old, in 2012/2013 this proportion had increased to 13% of replacement purchases. In particular the increase of broken appliances in this age group is noticeable. The highest replacement rates are recorded for tumble dryers and freezers: nearly 20% are replaced after being used for a maximum of years because they were broken.

5.1.3 Investigation at specialised recycling plants

In Germany, old electrical appliances are collected at the local authority recycling centres or by retailers and sent to specialised recycling plants. In many such plants, hundreds of washing machines were examined in 2004[27] and in 2013, and the following data recorded:

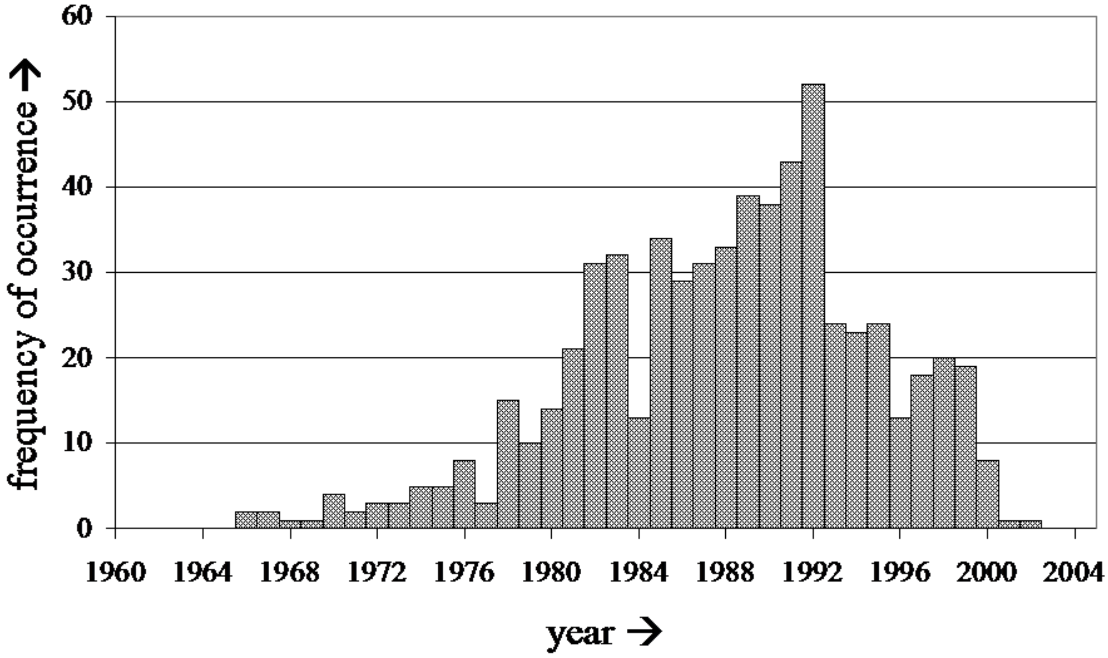
- Brand and model
- Product identification code
- Date of manufacture (from the installed capacitor)

However, it was not possible to obtain the relevant data for all washing machines. Information about brands and models only give a rough idea of the date of manufacture. And although every rating plate shows an identification number, decoding this requires a coding key which differs from manufacturer to manufacturer.

However, all washing machines contain a capacitor that is removed before shredding, which makes the capacitors a convenient source of information about the age of a washing machine, provided there is a correlation between the production dates of the capacitor and the washing machine. In the 2004 investigation both the date of manufacture washing machines and the production date of the capacitor could be decoded for 112 washing machines. Only a short time difference was found between the production dates (the average production month of the capacitor was October 1987, that of the washing machines November 1987). Thus the production date of the capacitor (Figure 22) can be used as a good indicator of the production date of the washing machine. While some of the investigated appliances were only a few years old, the oldest was nearly 40 years old. The mean year of manufacture was 1988, so that the machines were on average 16 years old at the time of disassembly. Assuming an interval of one year between manufacture and the original installation, and also assuming a period of six months between a washing machine breaking down and its being transported to a recycling plant, then the average period of use of washing machines in Germany is some 14 years. 20% der washing machines had a lifespan of more than 22 years.

[27] Stamminger, R.; Barth, A.; Dörr, S. 2005. "Old Washing Machines Wash Less Efficiently and Consume More Resources", In: *Hauswirtschaft und Wissenschaft*, 53(3), 124-31.

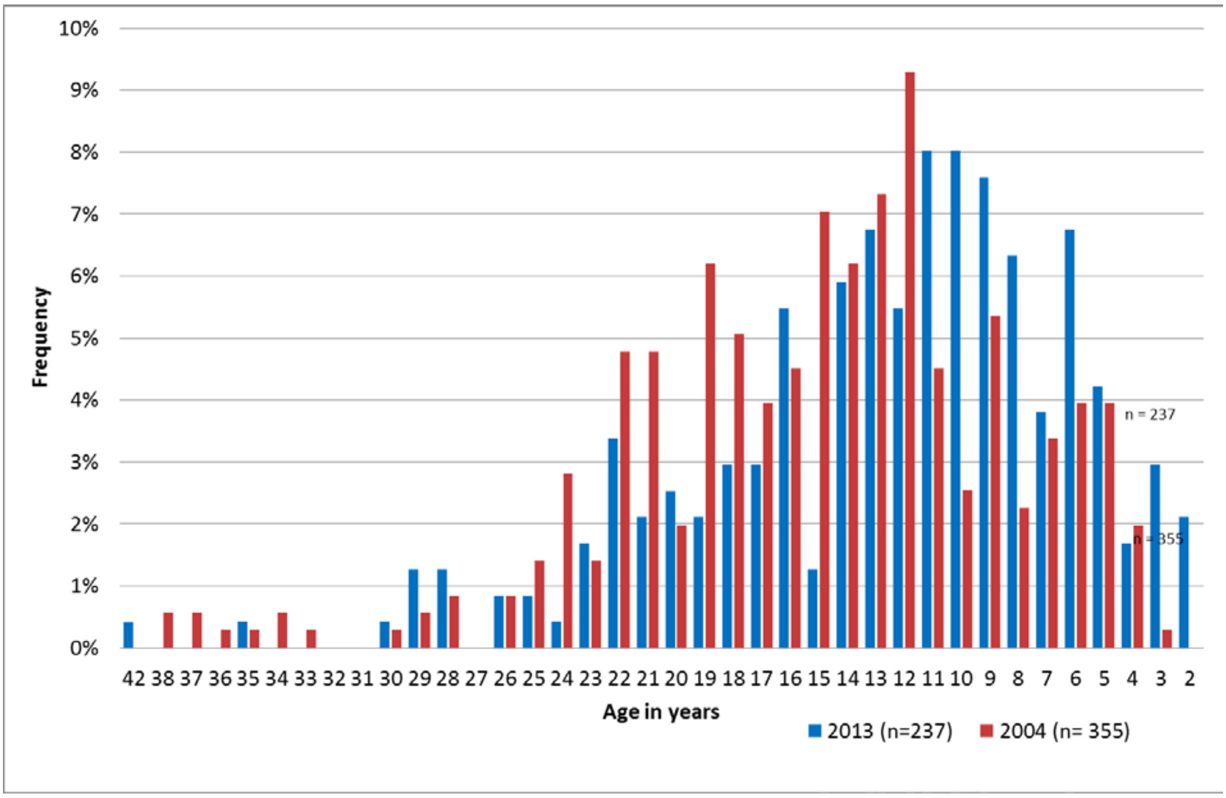
Figure 22 **Frequency of occurrence of capacitors in washing machines (y-axis) against year of production of the capacitor (x-axis) (n=625; Data collected in Germany, middle to the end of 2004)**



Source: Our presentation

A similar investigation was carried out at the end of 2013 and a total of 234 washing machines were disassembled and dated. For 61 machines it was possible to determine the production date of both the capacitor and of the washing machine itself. The mean deviation between the dates was 1.2 months, which confirms that the capacitor can be regarded as a good indicator of the production date of the washing machine.

Figure 23 Comparison of the residence time of washing machines (based on the capacitor production dates) for the collections in 2004 and 2013



Source: Our presentation

The average age of the recycled washing machines in 2013 was 13.7 years, which is much less than the 16 years identified in 2004. The age comparison (Figure 23) also shows that more washing machines were found in 2013 with residence times of 11 years or less. It is particularly striking that more than 10% of the washing machines in 2013 were only 5 years old or less (6% in 2004).

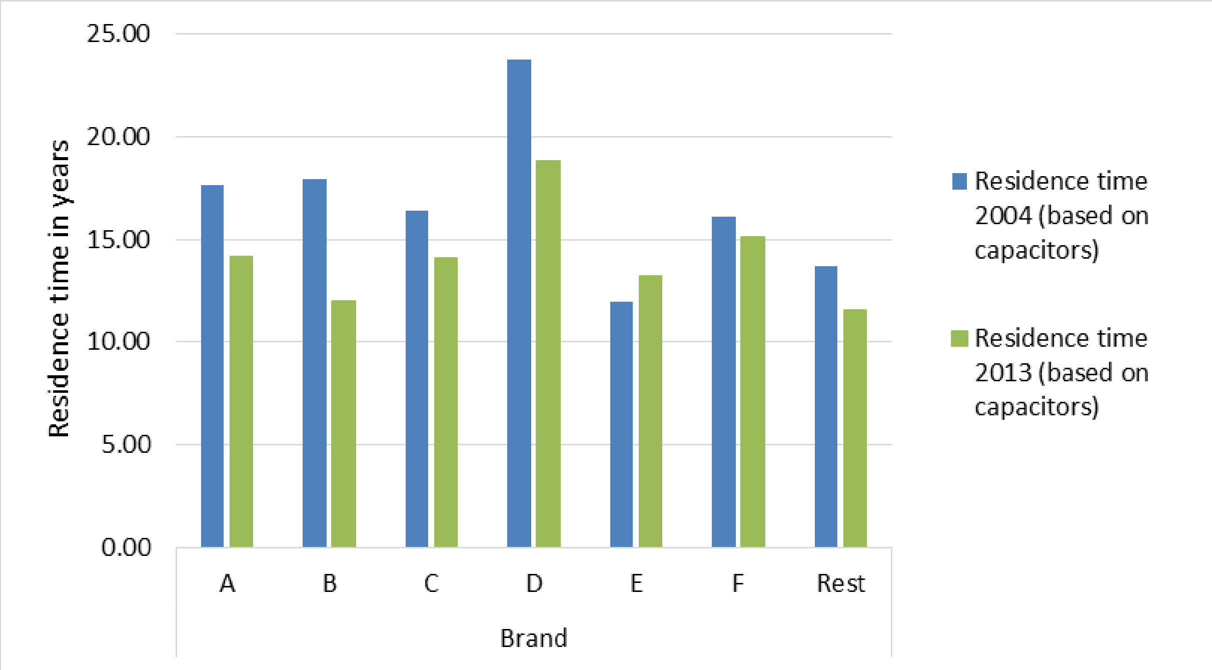
Reasons for this effect could be:

1. A general shortening of the lifespan of washing machines between 2004 and 2013;
2. The lifespans of washing machines from various manufacturers are becoming increasingly similar, in particularly for products with extremely long lifespans;
3. Washing machines on the market from new manufacturers have much shorter lifespans and these lower the average;
4. The behaviour for delivering old washing machines to local authority recycling centres has changed;
5. Older washing machines are increasingly being replaced by newer models offering potential savings from increased efficiency.

Further research is needed to determine which of the possible effects are most relevant.

A comparison of the data collected in terms of brands (at least 10 appliances of the same brand found) shows that for nearly all brands there has been a reduction in the residence time between 2004 and 2013 (Figure 24). However, the appliances that could not be allocated to the identified brands (‘Rest’ in Figure) showed an even lower residence time in households.

Figure 24 Comparison of the residence times of brands of washing machine in 2004 and 2013



Source: Our presentation

5.1.4 Lifespan tests of Stiftung Warentest

The German consumer association *Stiftung Warentest* has been testing the lifespans of washing machines under simulated household conditions regularly since 1993 and publishes the results together with reports on usability trials nearly every year.

The tests are carried out as specified by Stiftung Warentest in an external laboratory under the following conditions:

- Washing machines: 3 appliances of each type bought in shops
- Load: Cotton clothing to two-thirds of the rated full load for the machine
- Water hardness: medium
- Washing powder: "*Weisser Riese*" 12 g/kg load (if foaming: addition of foam inhibitor (SIK[28]))
- Test cycle with 8 programmes (6-7 x Cotton 20-90°C, 1-2 x Delicates programme)
- A total of approx. 230 test cycles are carried out (~1840 washes = 10-year operating life)
- 15-20-minute break between washes and a 30-minute break between cycles.

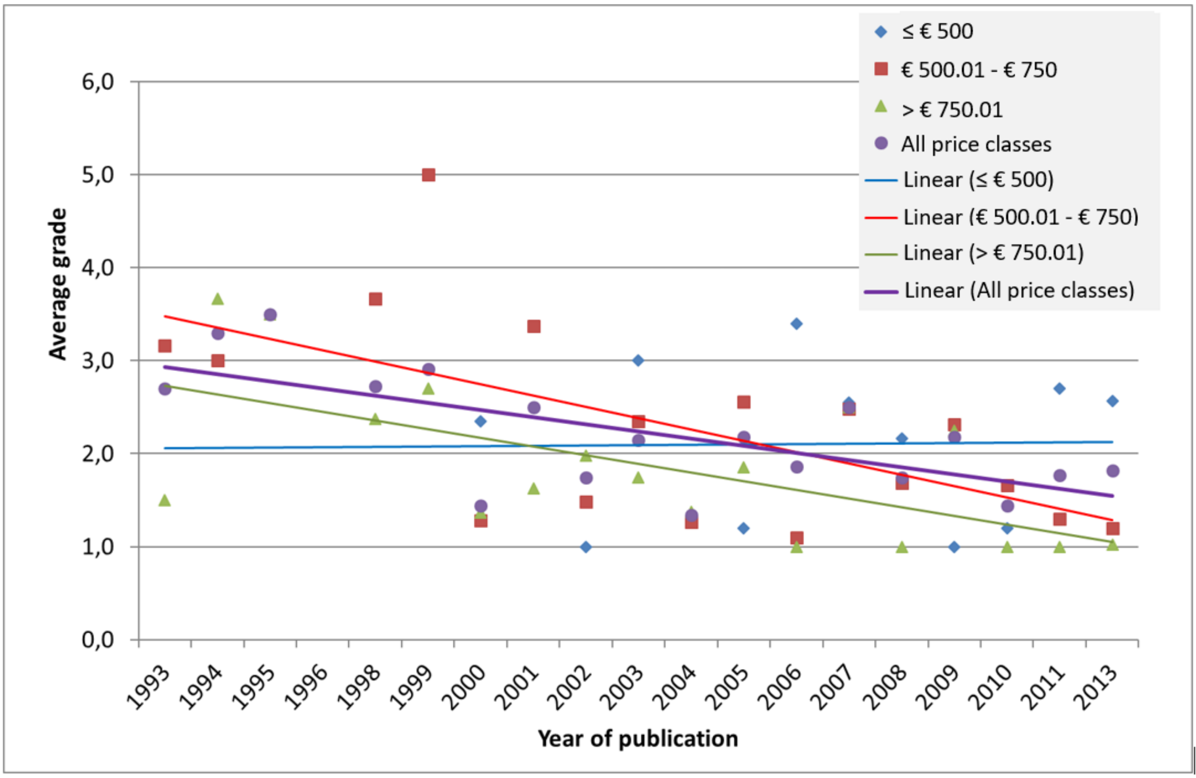
Completing these tests takes some 9 months, so that by the time the results are published some models may no longer be on the market.

The average results of the lifespan tests for washing machines in tests carried out by Stiftung Warentest (Figure 25) show a clearly improving trend, in particular for the most expensive

[28] SIK: Foam inhibitor concentrate, 8% silicon on inorganic carrier, in accordance with IEC 60456:1998 Clothes washing machines for household use – Methods for measuring the performance

appliances. In contrast, models costing less than € 500 have had nearly constant lifespans and in recent years have been noticeably worse than the more expensive models.

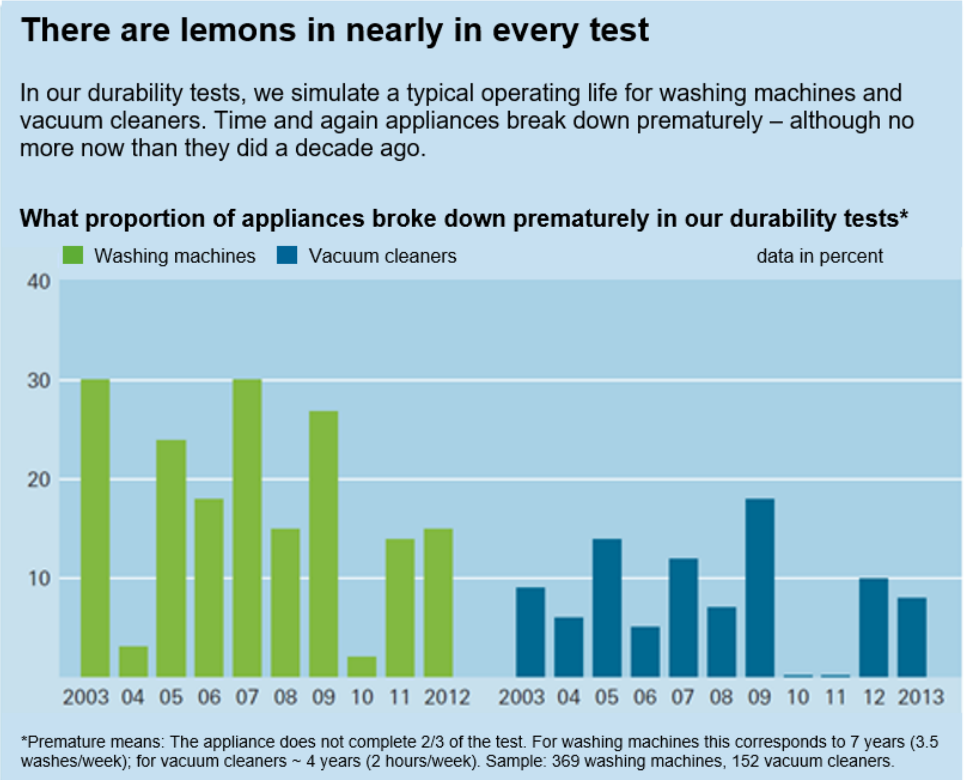
Figure 25 Average lifespans of washing machines in tests by Stiftung Warentest (1 High – 5 Low)



Source: Stiftung Warentest publication ('test'), our compilation

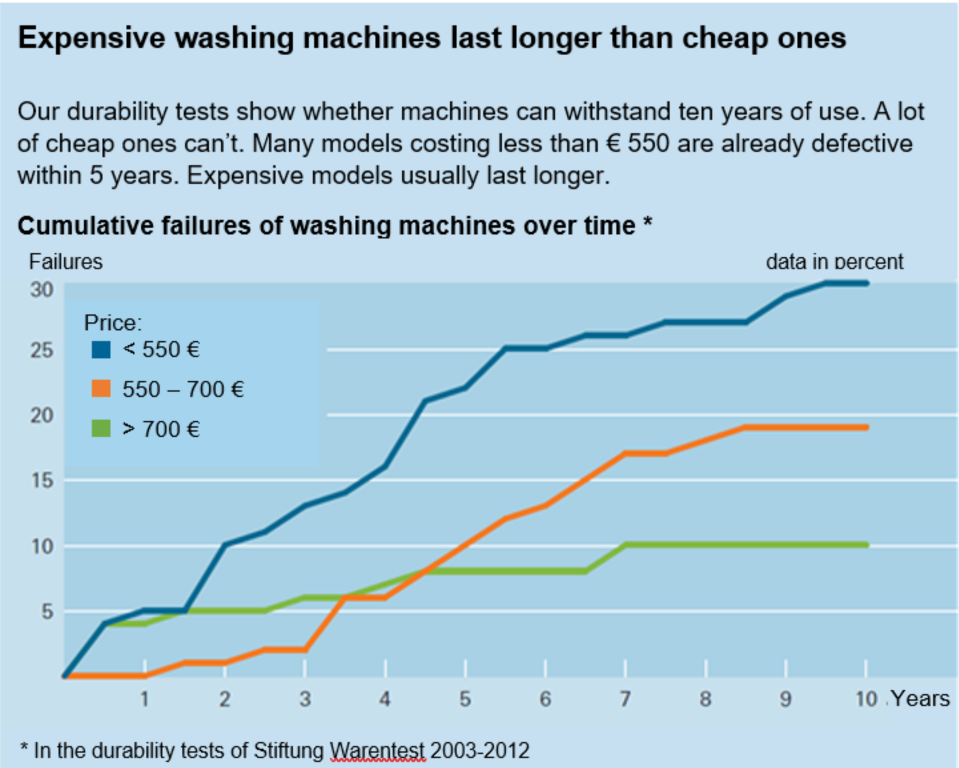
Stiftung Warentest published similar results for washing machines and vacuum cleaners in test 9/2013 for the period 2003 to 2013 (Figure 26). Three times more washing machines costing less than € 550 fail the durability test than machines costing € 700 and more (Figure 27). But overall, this evaluation shows that the durability of the tested washing machines and vacuum cleaners has improved considerably over the past decade, rather than declining. However, in all this time, Stiftung Warentest has not tested any washing machines on the market costing less than € 350.

Figure 26 Lifespan tests by Stiftung Warentest for washing machines and vacuum cleaners



Based on: test 9/2013, Stiftung Warentest (2013)

Figure 27 Correlation of lifespan and price for washing machines



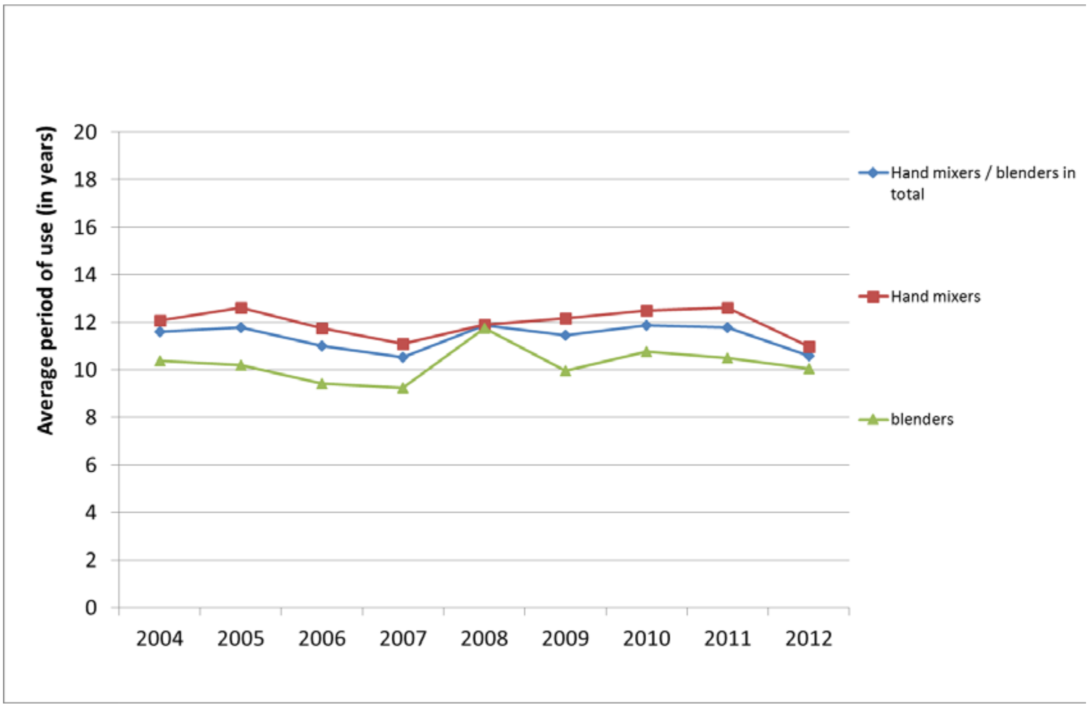
Based on: test 9/2013, Stiftung Warentest (2013)

5.2 Small household appliances (hand mixers and blenders)

From 2004 to 2012, GfK Society for Consumer Research collected data about the sales and prices of electric hand blenders and mixers, as well as the duration of the first use of replaced appliances and the main reasons for purchases in 20,000 representative German households (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The study did not cover the subsequent second use of functioning used appliances.

The analysis of the data shows that the average duration of the first use of electric hand mixers and blenders has hardly changed over the years (Figure 28). For both types of appliance, the average was 10.6 years in 2012. Considering the two types of appliance separately, we see a slight decline in the duration of the first use of hand mixers, from 12.1 years to 11.0 years (2012). The first useful service life of hand blenders is only slightly shorter, with an average of 10 years, irrespective of the reason for purchase.

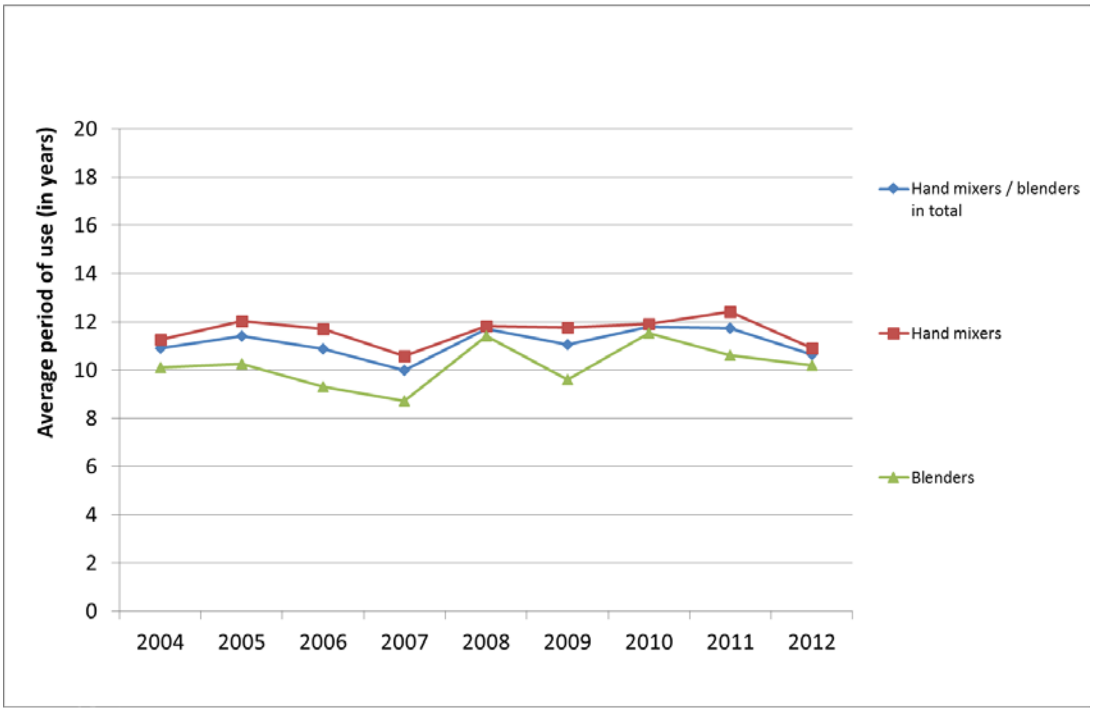
Figure 28 Average period of first use of replaced hand mixers and blenders (irrespective of reason for purchase)



Source: Our presentation, based on GfK data (n=1002 in 2012; lowest value n=527 in 2004)

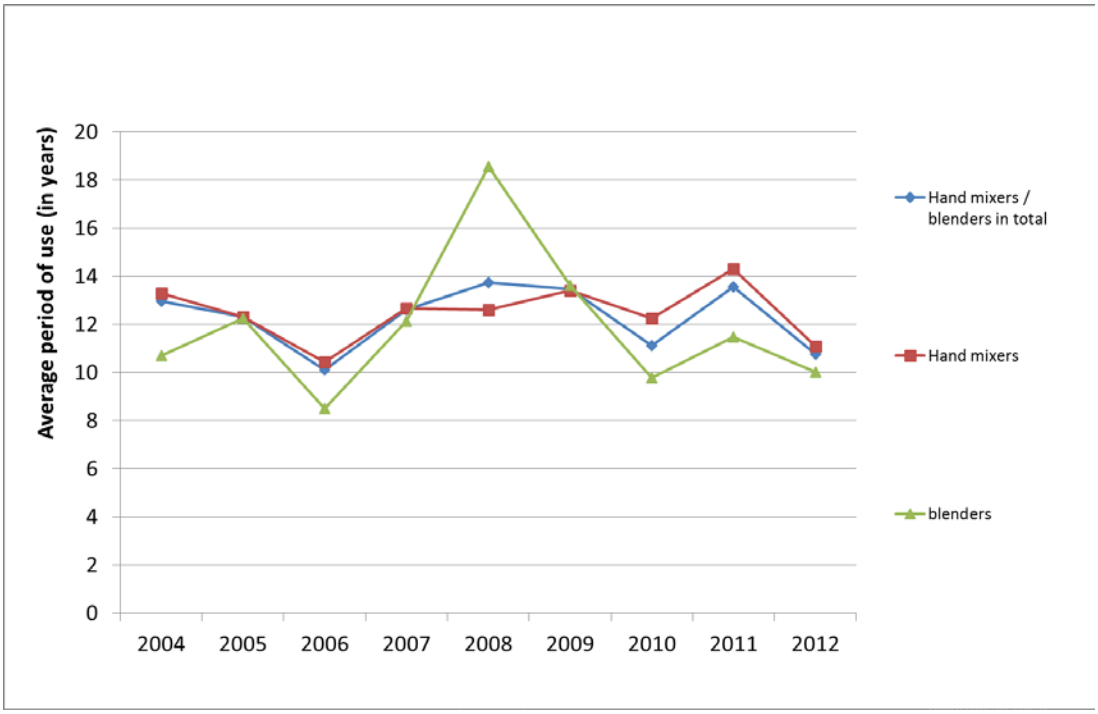
Over the years, there has hardly been any change in the first use period for electric hand mixers and blenders that were replaced because they were broken (Figure 29). On average the use period in this case is 10.6 years (2012).

Figure 29 Average period of first use of replaced 'broken' hand mixers[29]



Source: Our presentation, based on GfK data (n=759 in 2012; lowest value n=339 in 2004)

Figure 30 Average period of first use of replaced faulty/unreliable hand mixers[30]



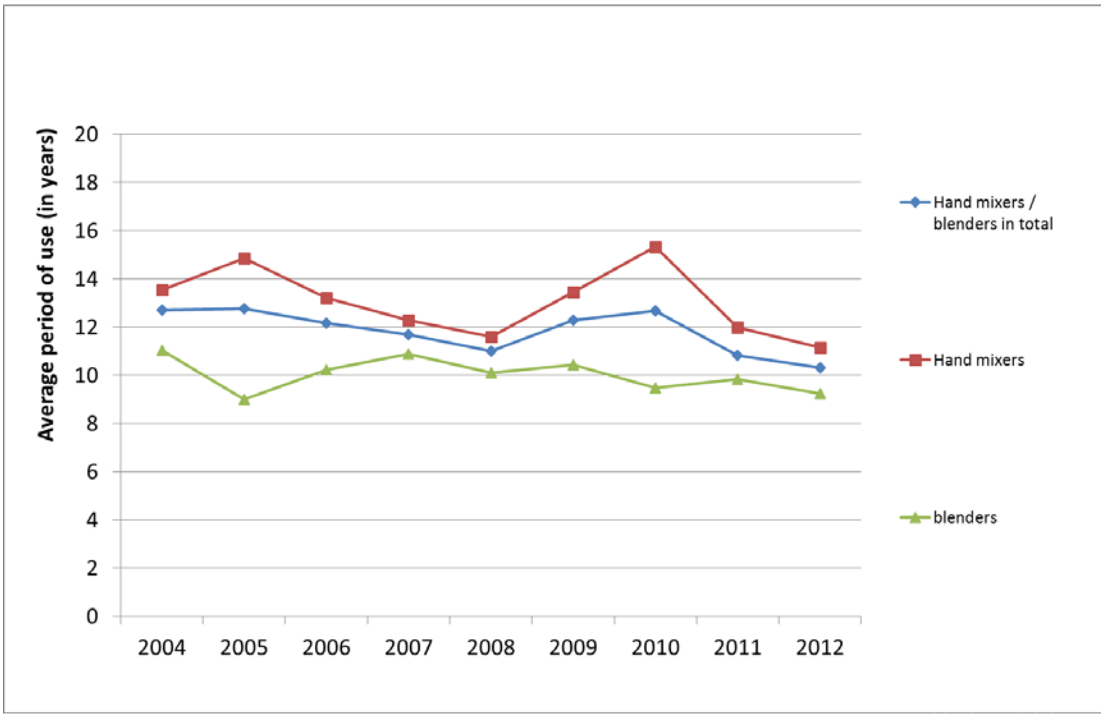
Source: Our presentation, based on GfK data (n=104 in 2012; lowest value n=83 in 2004; very few cases for electric hand blenders between 2004 and 2012)

[29] No distinction was made between irreparable appliances and those that could have been repaired or provided with replacement parts.

[30] Low numbers of hand blenders (< 50) for 2004-2012.

The results for faulty or unreliable appliances show fluctuations, which makes an interpretation more difficult. Considering the values for 2012, hand blenders were replaced after 10 years, and electric hand mixers showed a similar first use period of 11.1 years (Figure 30).

Figure 31 Average period of first use of hand mixers (and blenders) that still worked but were replaced by a better appliance[31]



Source: Our presentation, based on GfK data (n=139 in 2012; lowest value n=105 in 2004; very few cases between 2007 and 2009 for electric hand mixers, between 2004 and 2009 for hand blenders)

The first use period of electrical hand mixers and hand blenders that were still working but were replaced by a better appliance declined from 12.7 years (2004) to 10.3 years (2012) (Figure 31). With an average first use period of 11.2 years in 2012, hand mixers were used some two years longer than hand blenders. However, in some years there were very low numbers of reported purchases, especially for hand blenders. Between 2010 and 2012, there was only a minimal variation in the first use duration for hand blenders.

5.3 Consumer electronics

5.3.1 GfK survey

From 2004 to 2012, the GfK Society for Consumer Research collected data about the sales and prices of televisions as well as the duration of the first use of replaced appliances and the main reasons for purchases in 20,000 German households (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The surveys did not cover any subsequent second use of functioning replaced appliances. For the annual figures for the sales of TVs in Germany, GfK differentiated between CRT TVs[32], plasma televisions, and LCD televisions[33] (Panel market Germany, GfK 2003-2013). The results are shown in Figure 32. By 2009, sales of CRT televisions had fallen to

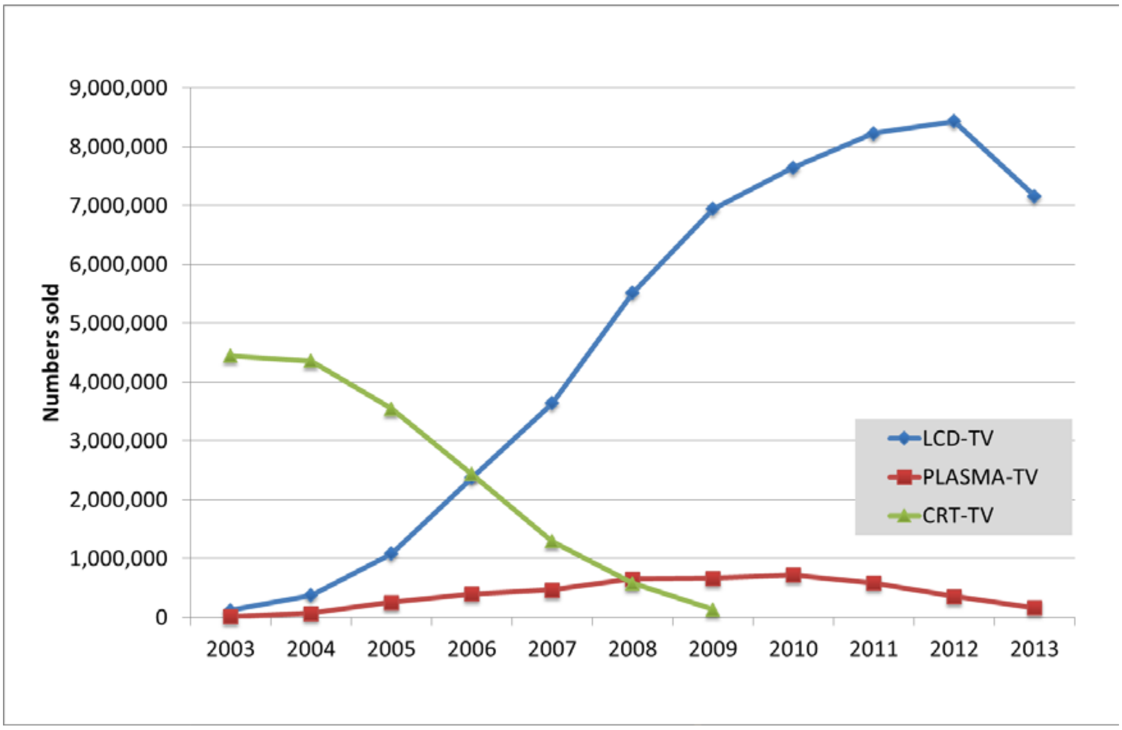
[31] Low numbers (< 50) in 2007, 2008 and 2009 for hand mixers, and 2004-2009 for hand blenders.

[32] Television with cathode ray tube (CRT)

[33] LCD = Liquid Cristal Display, colloquially flat screens.

near zero. The sales of LCD televisions increased rapidly, peaking at more than 8 million appliances in 2012, after which numbers fell again in 2013. The sales of plasma televisions increased gradually to more than 700,000 appliances in 2010 but had again fallen to some 164,000 by 2013.

Figure 32 Average sales of TVs[34]



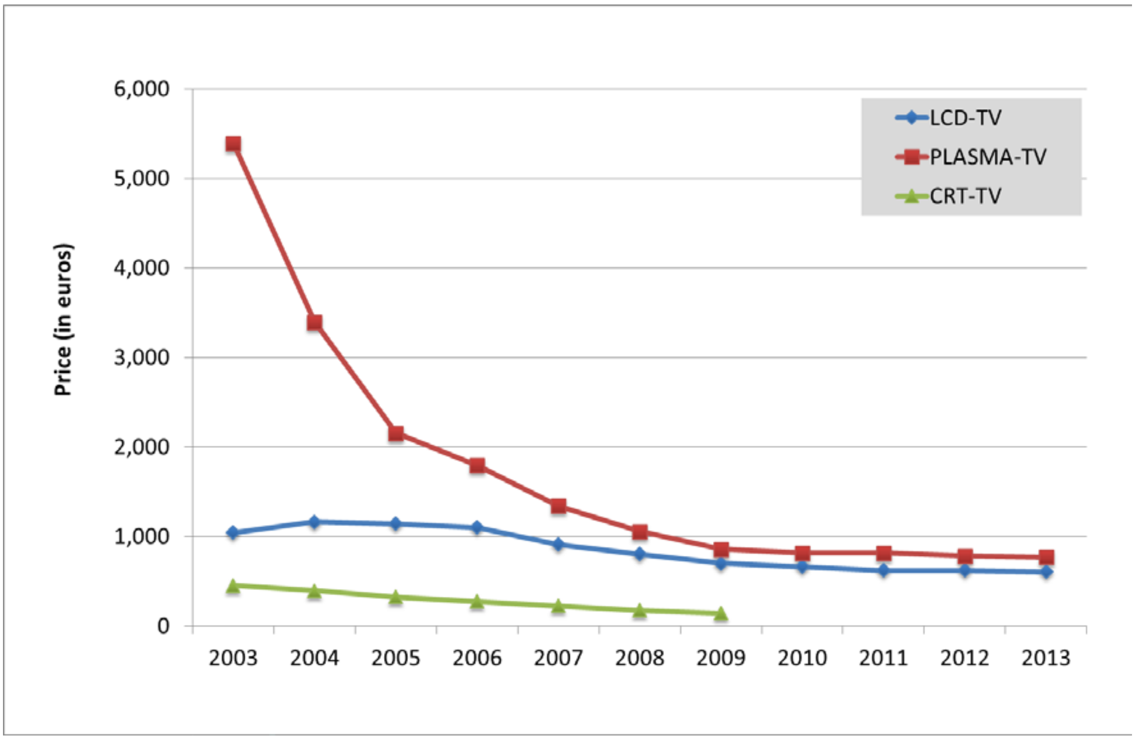
Source: Our presentation, based on GfK data

The GfK also monitored the prices consumers paid for the various types of television. The results are shown in Figure 33.

In particular, the market prices for plasma televisions fell sharply between 2003 and 2009 and then flattened out. The prices for CRT televisions fell continually between 2003 and 2009, until they were taken off the market in 2010. Prices for LCD televisions fell below an average price of € 1000 in 2006/2007, and by 2013 the average price was only about € 600.

[34] Data for sales and prices from the "Panel market GfK Trade Panel". GfK Panel market covers some 80% of sales in Germany.

Figure 33 Prices of televisions in Germany 2003–2013[35]

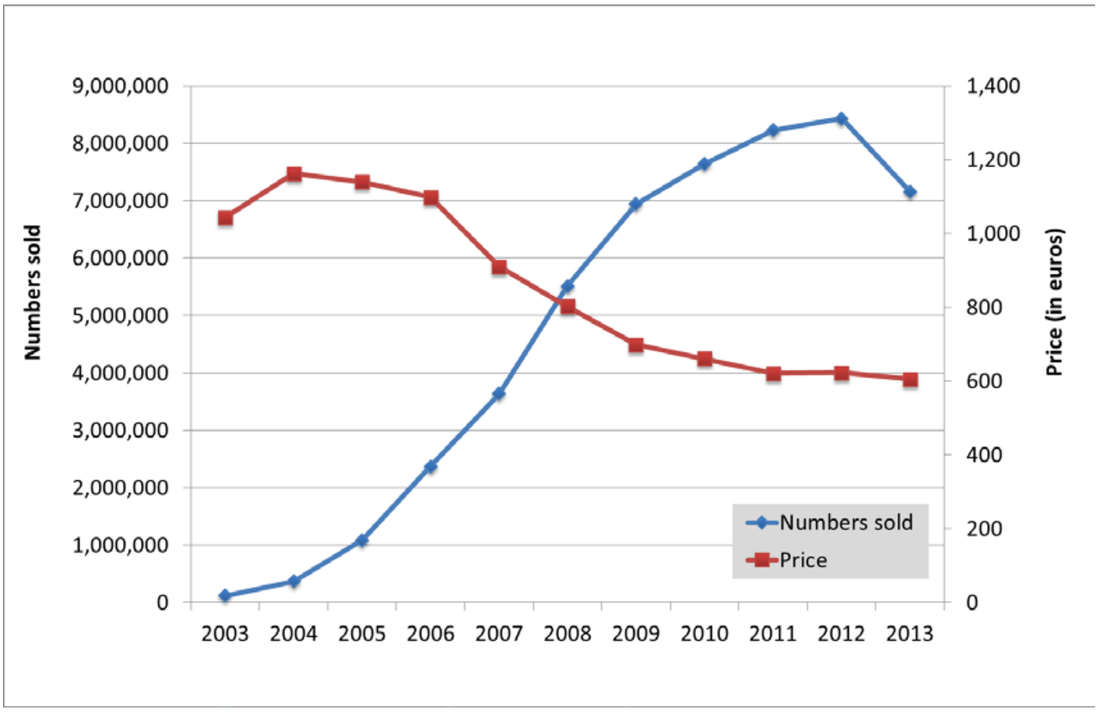


Source: Our presentation, based on GfK data

The following figures show comparisons of prices and the numbers sold for each type of television. Figure 34 shows how the numbers of LCD televisions corresponds to the drop in retail prices. Figure 35 clearly shows the “end” of CRT televisions on the German market. Although the prices fell dramatically, sales still plummeted because the old technology could no longer compete with the new LCD televisions. Figure 36 shows that sales of plasma televisions increased between 2003 and 2010 while the prices fell rapidly. However, sales then fell sharply because plasma televisions were also unable to match the LCD technology.

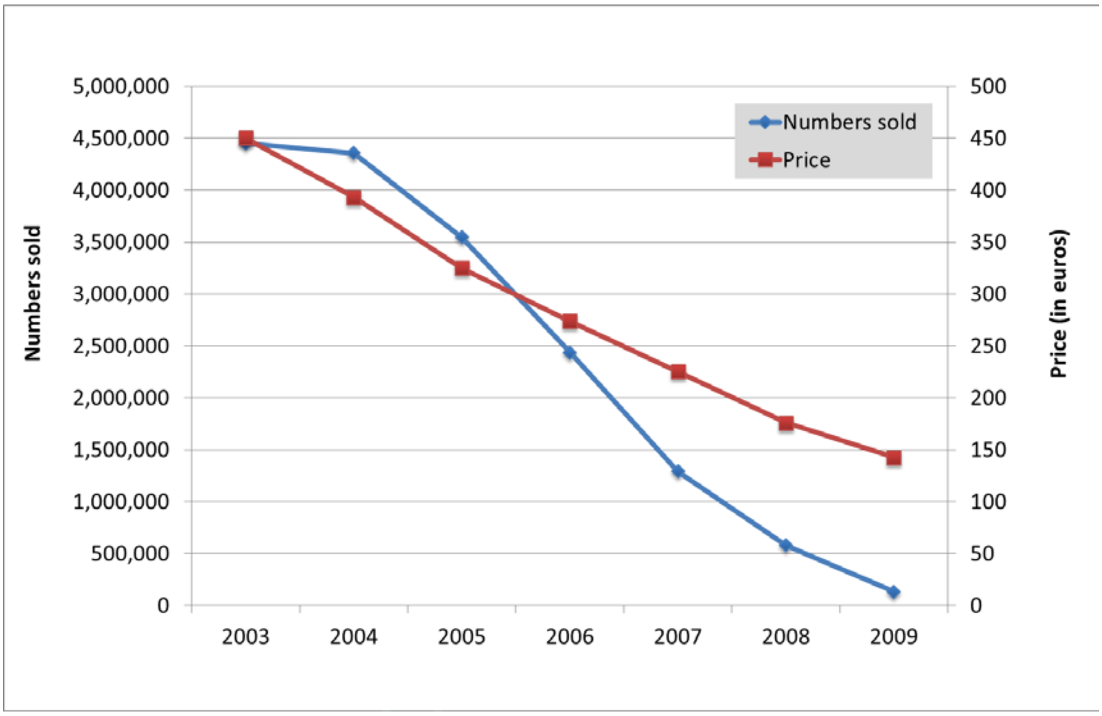
[35] Data for sales and prices from the “Panel market GfK Trade Panel“. GfK Panel market covers some 80% of sales in Germany.

Figure 34 Sales and prices of LCD televisions, 2003–2013[36]



Source: Our presentation, based on GfK data

Figure 35 Sales and prices of CRT televisions 2003–2013[37]

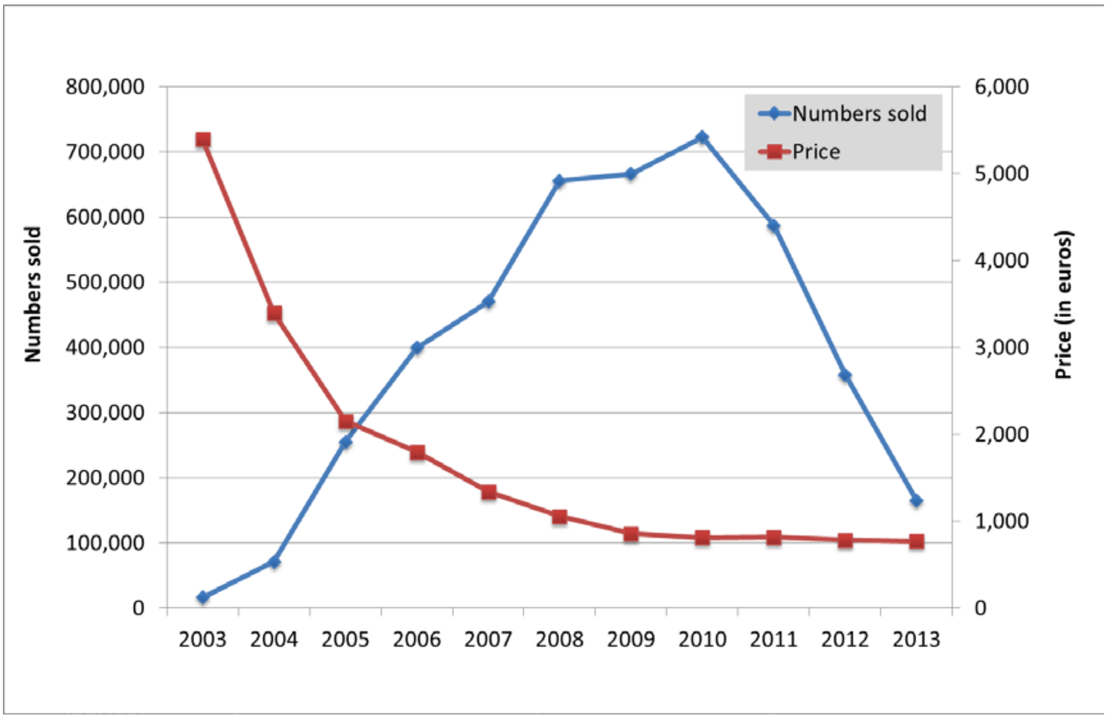


Source: Our presentation, based on GfK data

[36] Data for sales and prices from the "Panel market GfK Trade Panel". GfK Panel market covers some 80% of sales in Germany.

[37] Data for sales and prices from the "Panel market GfK Trade Panel". GfK Panel market covers some 80% of sales in Germany.

Figure 36 Sales and prices of plasma televisions from 2003-2013[38]



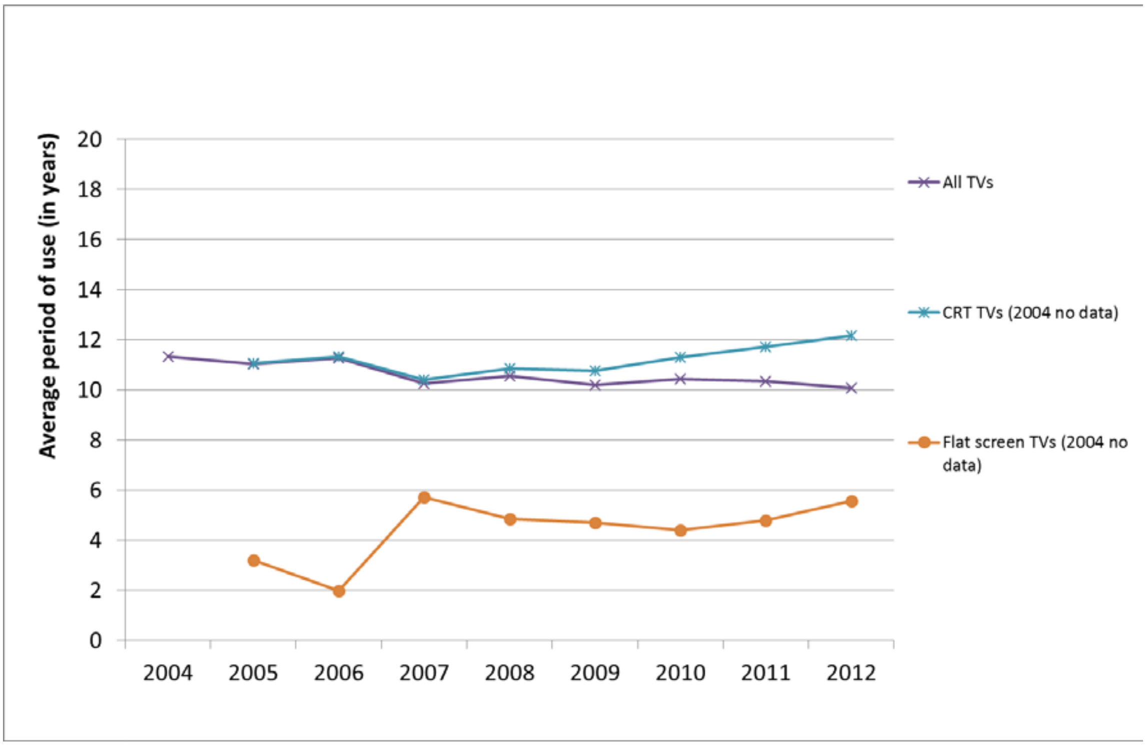
Source: Our presentation, based on GfK data

The GfK Society for Consumer Research also carries out surveys every year in households in Germany of the age of selected electrical appliances when a replacement is purchased (GfK Consumer Panel 2004-2012). The responses can be used to derive the average duration of the first use of the replaced appliances. In the following, the data for televisions is used to derive average periods of first use.

Figure 37 shows very different developments for flat screen TVs and CRT televisions.

[38] Data for sales and prices from the "Panel market GfK Trade Panel". GfK Panel market covers some 80% of sales in Germany.

Figure 37 Average period of first use of replaced TVs in Germany



Source: Our presentation, based on GfK data (All TVs, n=3087 in 2012; lowest value n=1290 in 2004; very low numbers for flat screen TVs in 2005 and 2006)

Whereas the average first use period for CRT televisions in 2005 and in 2006 was 11.1 and 11.3 years, respectively, it fell in 2007 to 10.4 years, before increasing steadily in the years 2008 to 2012 from 10.9 to 12.2 years.

In contrast, flat screen TVs (LCD and plasma televisions) had an average use period in the first years of the surveys of 3.2 years in 2005 and 2.0 years in 2006. However, in view of the very small numbers involved, these values are not representative. In 2007, the first use period was 5.7 years and this had declined to 4.4 years by 2010. Representative numbers had become available by this time. Over the following two years the average first use duration increased to 5.6 years (Figure 37).

The average first use period of replaced flat-screen televisions is much shorter than that of replaced CRT televisions. However, when making comparisons it should be borne in mind that the transition to flat-screen TVs represents an innovative step in the technology.

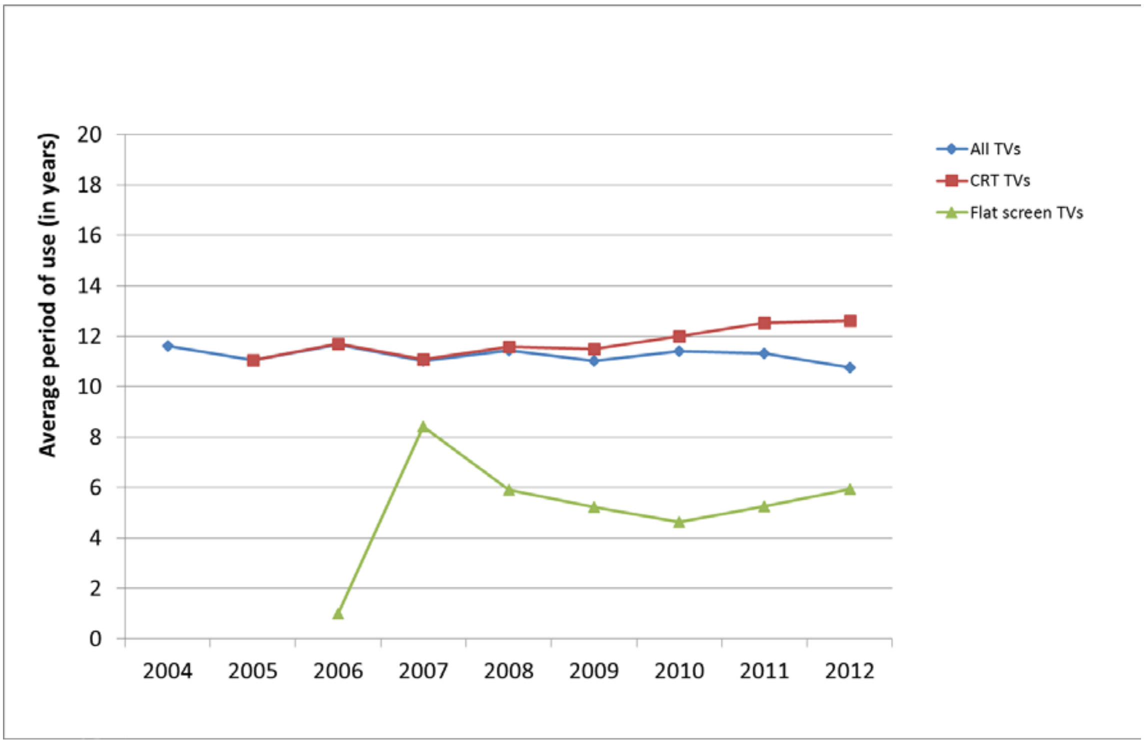
Overall, there has been a downward trend in the average first use periods for the replaced televisions (CRT and flat-screen televisions) from year to year. This is attributable to the continually increasing proportion of flat-screen TVs, from only 3% in 2007 to 31% in 2012.

In the following, the average first use period of old appliances is considered according to the main reason given for the replacement purchase. The main reasons were:

1. “The old appliance broke.”
2. “The old appliance was faulty/unreliable.”
3. “The old appliance worked but I/we wanted a better one.”

Figure 38 shows a slight decrease in the average first-use period of all TVs replaced because they were defective, from 11.6 years in 2004 to 10.8 years in 2012. Of these, CRT TVs showed a slight increase in the first-use period over the years 2005–2012. Whereas in 2005 they were used for an average of 11.1 years before breaking and being replaced, this increased to 12.6 years in 2012.

Figure 38 Average period first use of televisions replaced because “The old appliance broke” [39]



Source: Our presentation, based on GfK data (All TVs, n=877 in 2012; lowest value n=771 in 2006; very few cases for Flat screen TVs between 2006 and 2008)

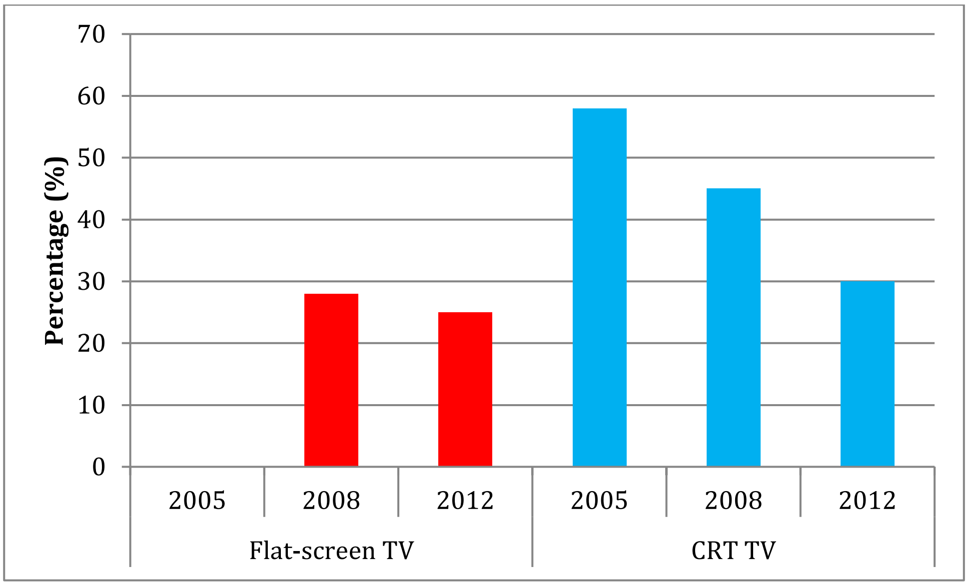
The situation is different for flat-screen TVs. The numbers are too small in the years 2006-2008 to draw statistically meaningful conclusions (< 40). In 2009, the average first use period for appliances replaced because they were defective was 5.2 years, falling to 4.6 years in 2010, and then increasing to 5.2 in 2011 and 5.9 years in 2012.

Overall, the period of use before an appliance is replaced after becoming defective is much shorter for flat-screen TVs than for CRT televisions. The average first-use period for all TVs replaced because of a defect showed a downward trend. This is because of the increasing numbers of flat-screen televisions and their relatively short lifespan compared to CRT televisions.

However, Figure 39 also shows a slight decrease in the proportion of product replacements for defective flat-screen TVs between 2008 and 2012, from 28% to 25%.

[39] No distinction was made between irreparable appliances and those that could have been repaired or provided with replacement parts.

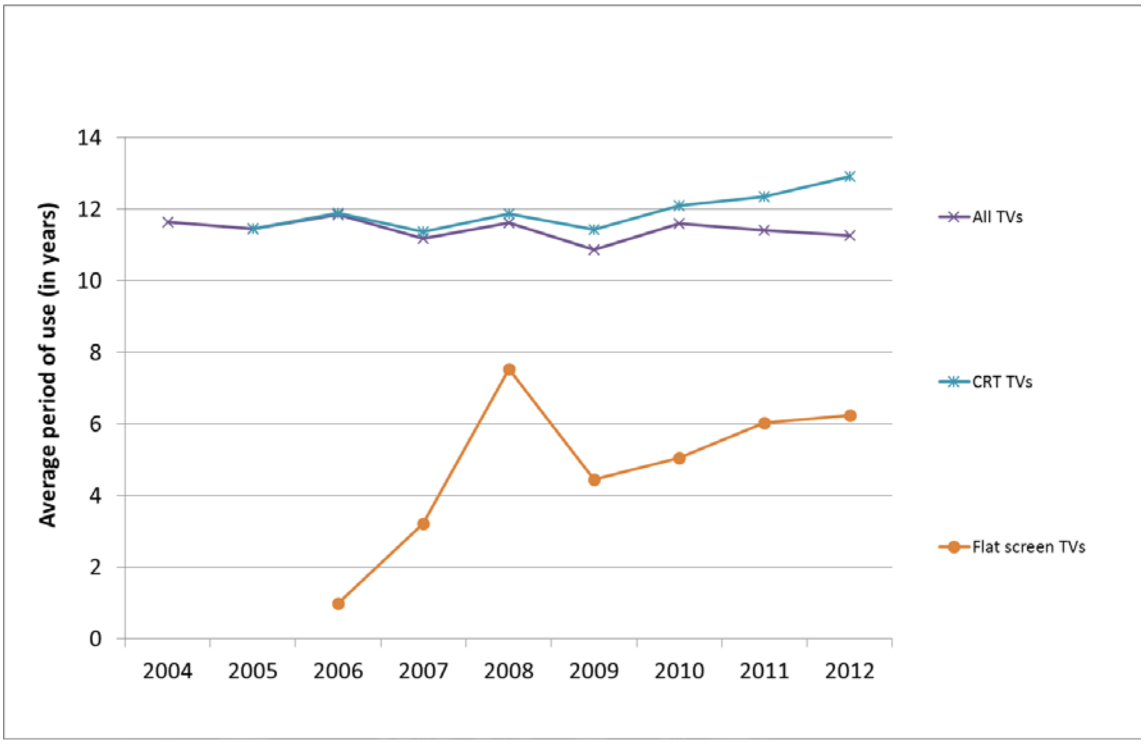
Figure 39 Proportion of product replacements for defective TVs



Source: Our presentation, based on GfK data

Figure 40 shows that the period of use until an appliance develops faults or becomes unreliable is much shorter for flat-screen televisions than for CRT televisions. The average first-use period for faulty flat-screen televisions was 6.0 years in 2011 and 6.2 years in 2012 (very few cases for 2006-2010). In contrast, CRT televisions were only replaced because they had become faulty or unreliable after being used for 11.5 years (2005) or 12.9 years (2012).

Figure 40 Average first-use period for televisions replaced because “The old appliance was faulty or unreliable”

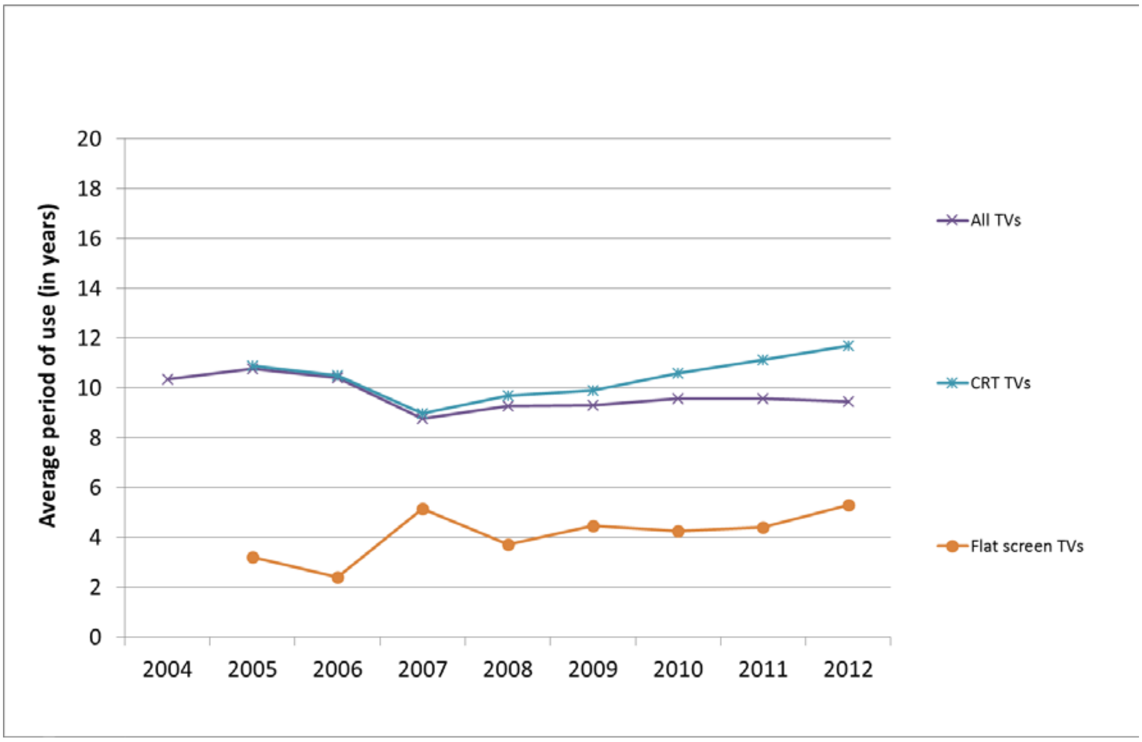


Source: Our presentation, based on GfK data (All TVs, n=442 in 2012; lowest value n=214 in 2006; very few cases for Flat screen TVs between 2006 and 2010)

Because of the growing proportion of flat-screen televisions, the average period of first use of all faulty or unreliable replaced televisions fell slightly over time. In 2004, televisions in this group were replaced after 11.7 years of use, in 2012 after 11.3 years.

Figure 41 shows the development of the average period of first-use of televisions that were replaced because the purchaser wanted a better appliance, even though the old one was still in working order.

Figure 41 Average period of first-use of televisions replaced primarily because "The old appliance worked but I/we wanted a better one"



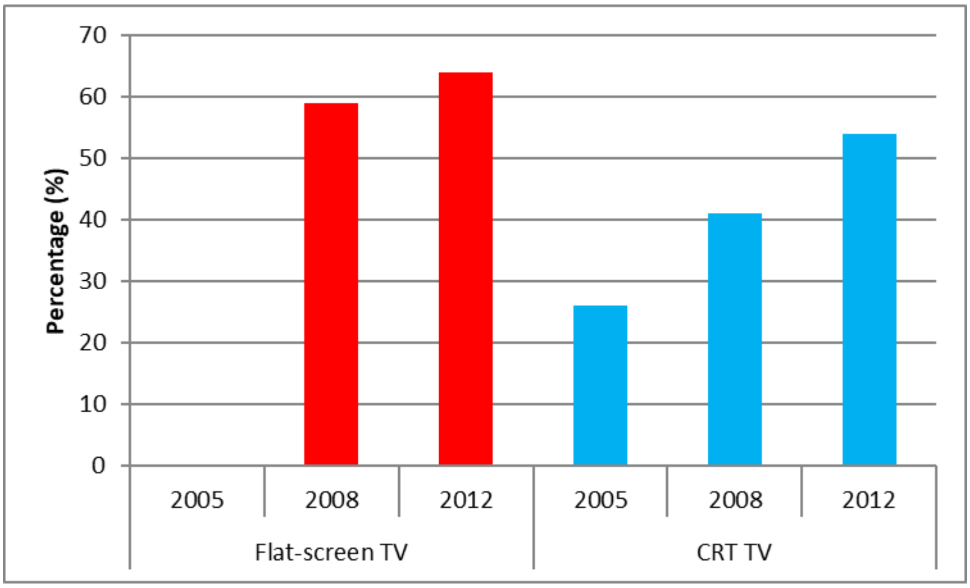
Source: Our presentation, based on GfK data (All TVs, n=1768 in 2012; lowest value n=289 in 2004; very few cases for flat-screen TVs from 2005 to 2007)

It is noticeable that the wish for a new (and better) appliance arises sooner among owners of flat-screen televisions. In 2008, the replaced flat-screen television was on average 3.9 years old, rising to 5.3 years by 2012.[40] In contrast, functioning CRT televisions were replaced by a better one after 9 years in 2009, increasing to 11.7 years in 2012. Considering all TVs, the first-use period of televisions that were still in working order but were replaced by a better one increased from just above 10 years before 2007 to values just below 10 years after 2007. It should be noted that the innovation cycles have shortened drastically since the introduction of flat-screen TVs. Innovations affect the duration of first-use if purchasers want a more innovative appliance. And they may then continue to use their old TV as a second appliance, although this cannot be determined from the available data.

Figure 42 shows that in 2012, for example, more than 60% of the functioning flat-screen televisions were replaced because the consumers wanted a better TV.

[40] Until 2007, the numbers of flat-screen televisions were not representative (n < 50).

Figure 42 Proportion of TVs that were still working but were replaced by a better TV

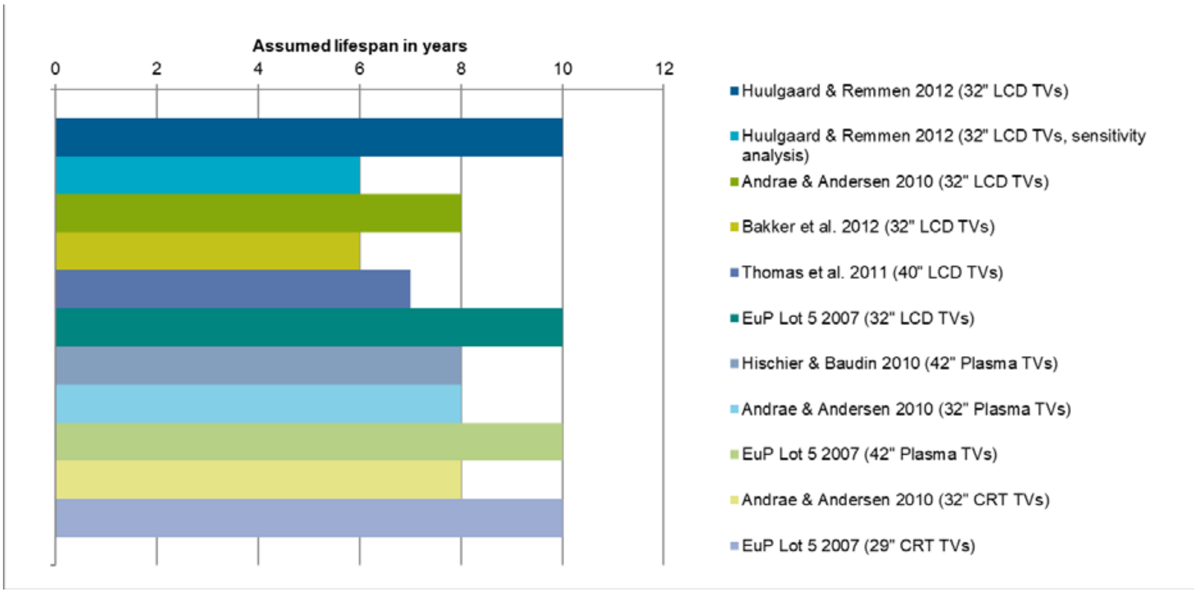


Source: Our presentation, based on GfK data

5.3.2 Evaluation of scientific studies and product tests

In this section, we report on life-cycle studies on the lifespan of televisions found in the literature. Figure 43 gives an overview of the results.

Figure 43 Assumed lifespans of televisions in published life-cycle assessments



Source: JRC (2014a)

Figure 43 shows how widely the assumptions about the lifespan of televisions vary. For LCD televisions they range from 6 years by Bakker et al. (2012) to 10 years by Huulgaard & Remmen (2012).

For plasma televisions, lifespans of between 8 years (Hirschier & Baudin 2010) and 10 years (EuP Lot 5 2007) are assumed. For CRT televisions. Andrae & Anderson (2010) assume a lifespan of 8 years, EuP Lot 5 (2007) assumes 10 years.

It is not possible to identify any clear trend for the development of lifespans (longer or shorter) on the basis of the available data.

Stiftung Warentest is not able to test the lifespan of televisions, because such tests would take too long. (According to Stiftung Warentest, a test simulating seven years of use would take eighteen months). Many models would no longer be on the market by the end of the test (Stiftung Warentest 2013).

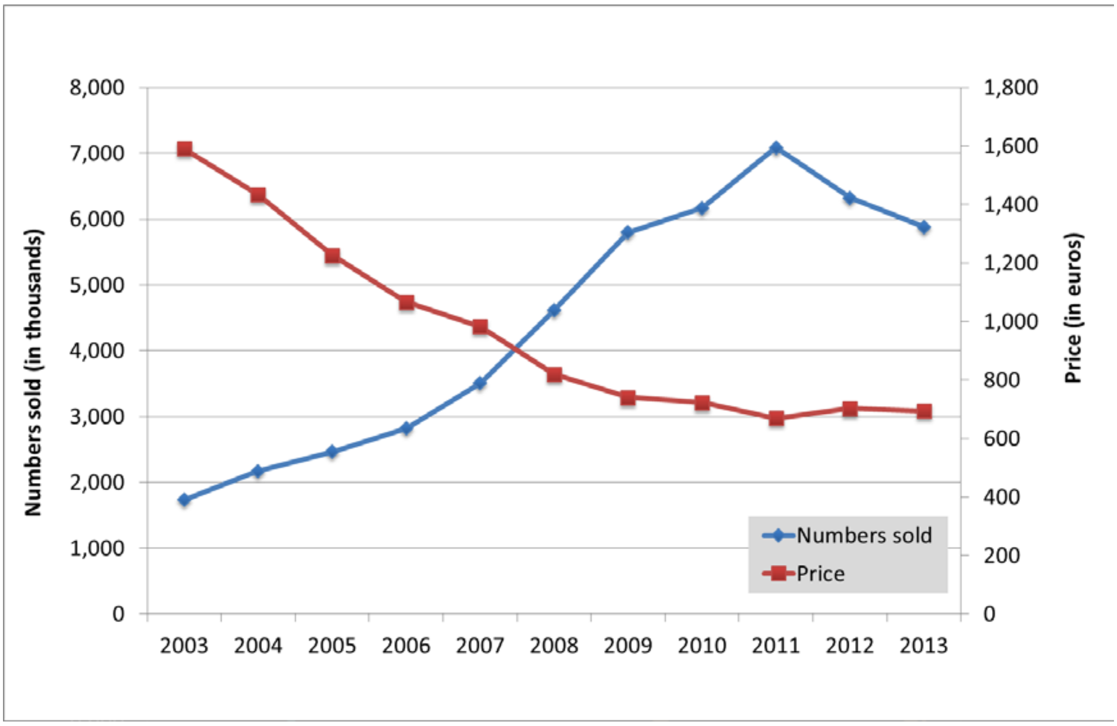
5.4 Information and communication technology

5.4.1 GfK survey

In the period from 2004 to 2012, the GfK Society for Consumer Research collected data about the sales and prices of laptops as well as the duration of the first use of replaced appliances and the main reasons for purchases in 20,000 German households (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The study did not cover the subsequent second use of functioning used appliances.

The results are shown in Figure 44. The average price of laptops fell from about € 1600 in 2003 to € 600 in 2013. Over the same period, the sales increased from below 2 million to a peak of more than 7 million in 2011. The numbers of laptops sold then fell again to below 6 million in 2013 due to the increasing prevalence of additional appliances such as Tablet PCs.

Figure 44 Sales and average prices of laptops between 2003 and 2013[41]

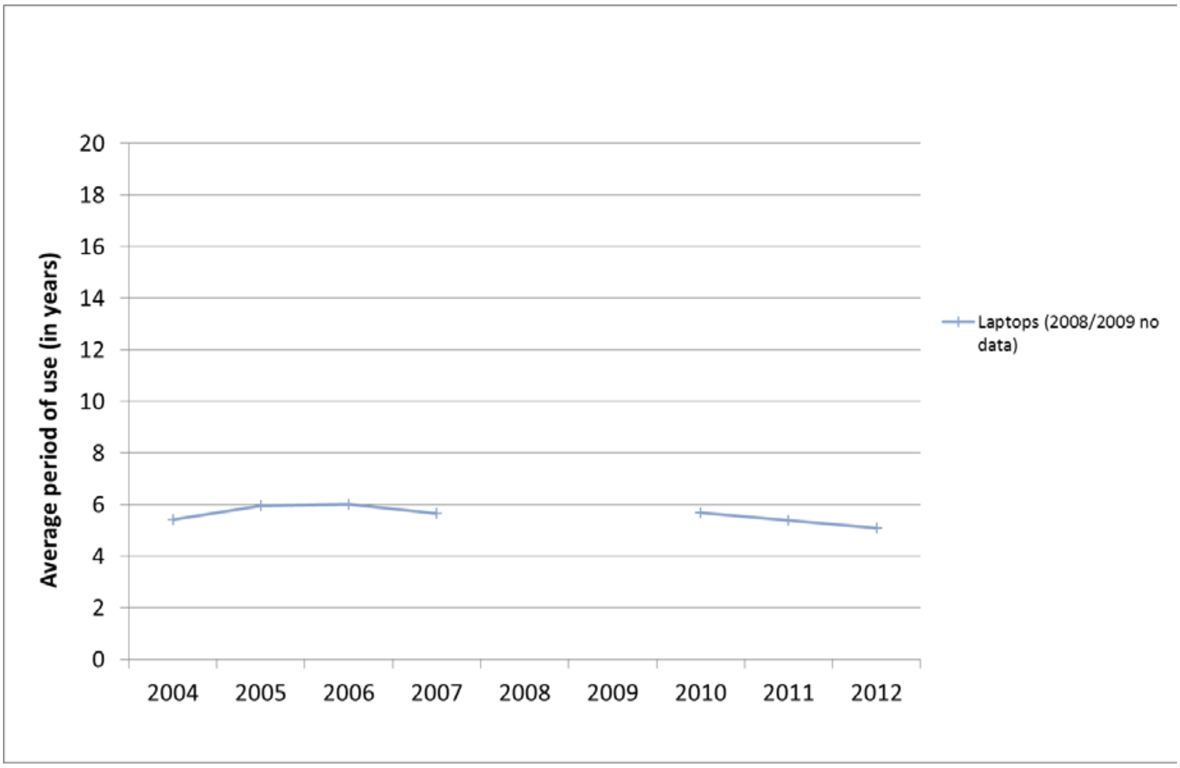


Source: Our presentation, based on GfK data

[41] Data for sales and prices from the "Panel market GfK Trade Panel". GfK Panel market covers some 80% of sales in Germany.

GfK has also collected data about the average first use of laptops in Germany in the years 2004–2007 and 2010–2012 (GfK Consumer Panel 2004-2012).[42] Figure 45 shows that the average first use period between 2004 and 2007 at first increased slightly from 5.4 years (2004) to 6 years (2005/2006) and fell again in 2007 to 5.7 years. In 2012, the average first-use period for laptops fell further to 5.1 years. This survey covers laptops that were replaced by a new one, whatever the reason for the replacement (Figure 45).

Figure 45 Average period of first use of laptops in Germany (irrespective of reason for purchase)



Source: Our presentation, based on GfK data (n=2268 in 2012; lowest value n=244 in 2004)

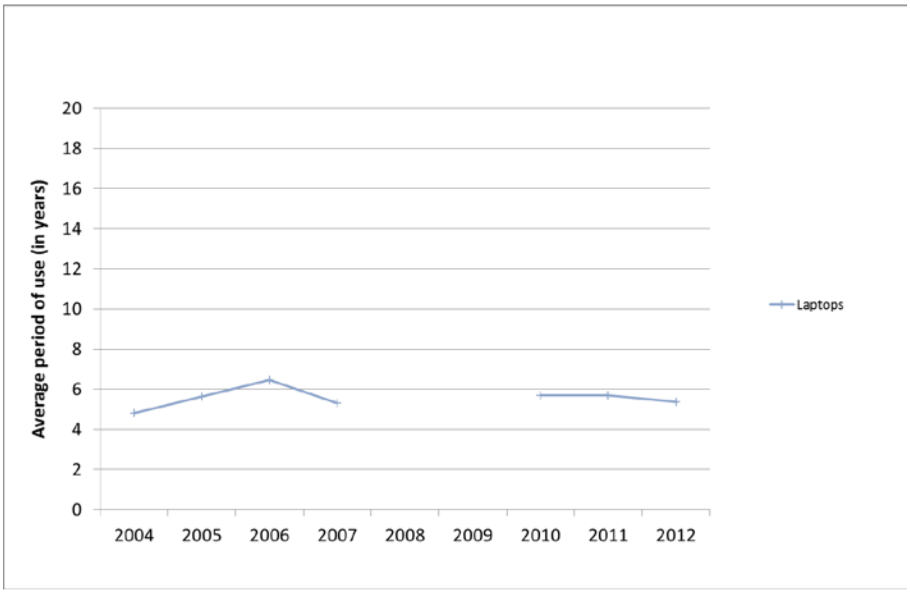
In the following, the average first use period of old appliances is considered according to the main reason given for the replacement purchase. The main reasons were:

1. “The old appliance broke.”
2. “The old appliance was faulty / unreliable.”
3. “The old appliance still worked but I/we wanted a better one.”

Figure 46 shows the average period of first use of laptops in Germany that were replaced because they were defective. In the years 2010–2012 the average first-use period was between 5.7 and 5.4 years. Only very small numbers of responses were available for the years 2004–2007. The evaluation of the existing figures gives an increase in the average first use period from 4.8 years in 2004 to 6.5 years in 2006, then a drop in 2007 to 5.3 years.

[42] For 2008 and 2009, GfK has no data about the average duration of the first-use of laptops (GfK Consumer Panel 2004-2012).

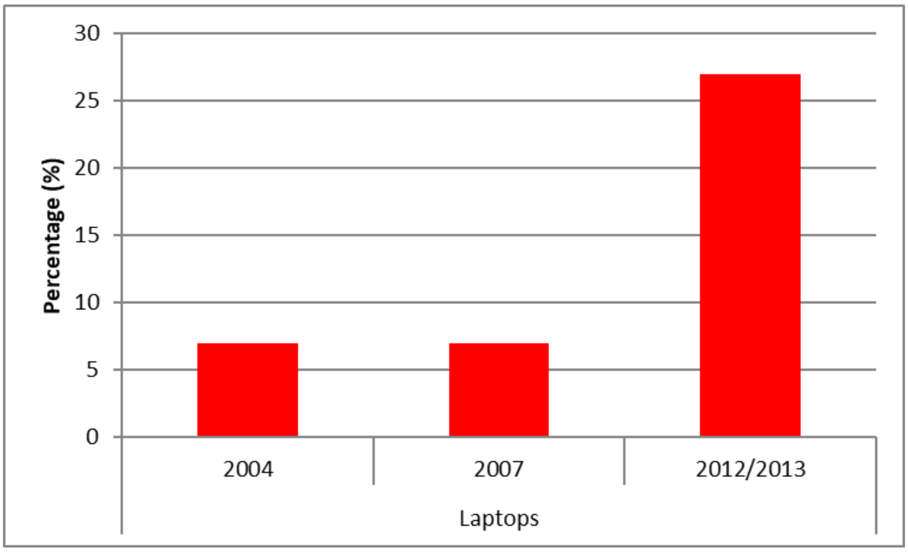
Figure 46 Average period of first-use of laptops replaced primarily because "The old appliance broke"[43]



Source: Our presentation, based on GfK data (n=622 in 2012; lowest value n=17 in 2004; very few cases from 2004 to 2007)

It is not possible to identify any clear trend from this dataset about whether laptops are more likely to become defective over the years. However, Figure 47 shows that there has been a clear increase in the proportion of defective laptops among all replaced laptops in comparison with the surveys in 2004 and 2007, and by 2012/2012 these represented more than 25% of the total.

Figure 47 Proportion of product replacements for defective laptops

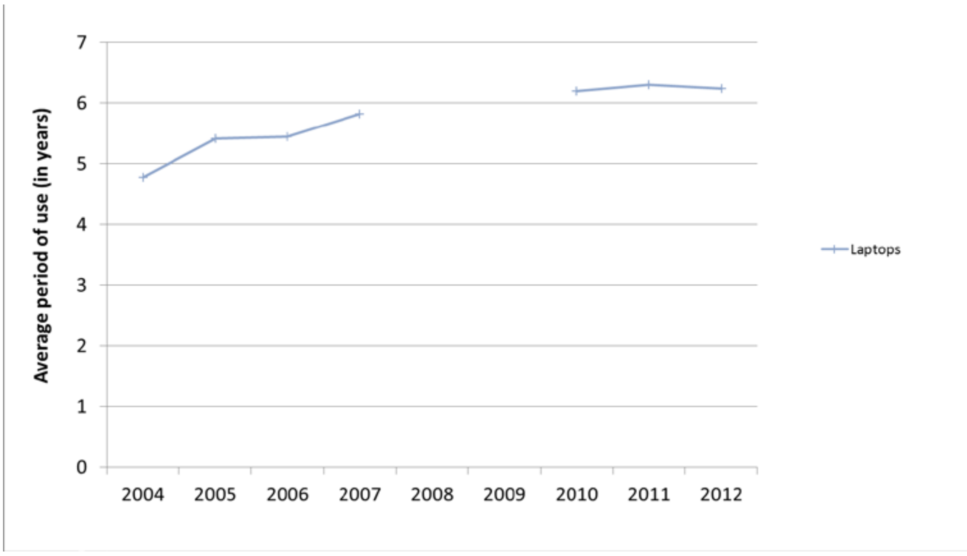


Source: Our presentation, based on GfK data

Figure 48 shows that laptops that were replaced because they were faulty or unreliable had been in use for an average of 4.8 years in 2004 (small numbers in the period 2004-2007). By 2012, the average first-use period had increased to 6.3 years in 2011 and 6.2 years in 2012.

[43] No distinction was made in the survey between irreparable appliances and those that could have been repaired or provided with replacement parts.

Figure 48 Average first-use period of laptops replaced primarily because "The old appliance was faulty / unreliable"

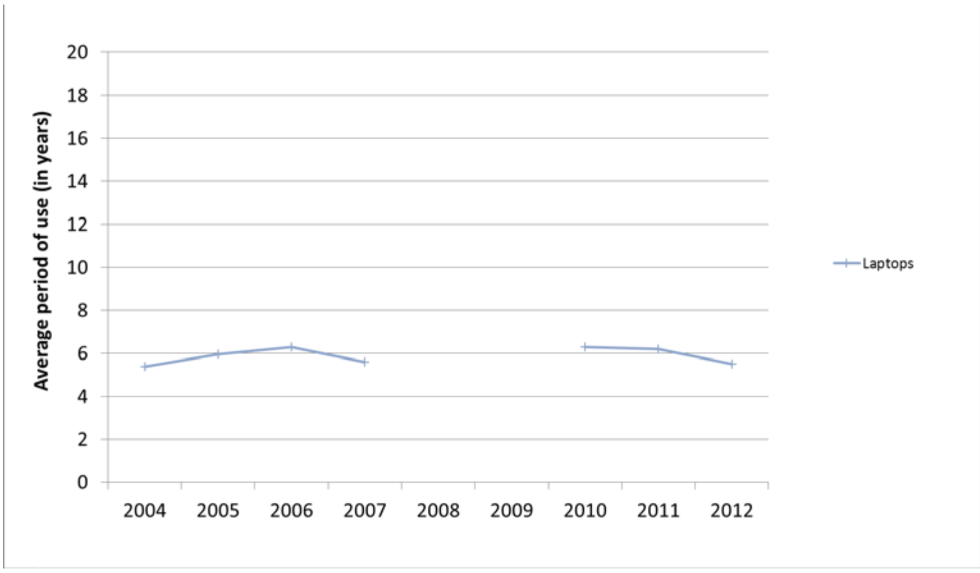


Source: Our presentation, based on GfK data (n=352 in 2012; lowest value n=23 in 2004; very few cases from 2004 to 2007)

Figure 49 shows the average first-use period of laptops replaced between 2004 and 2012 that still worked but where the consumer wanted a better one. In this case the average first-use period was about 6 years, with only slight deviations from this value.

It is not possible to identify any clear trend for the development of lifespans (longer or shorter) on the basis of the available data.

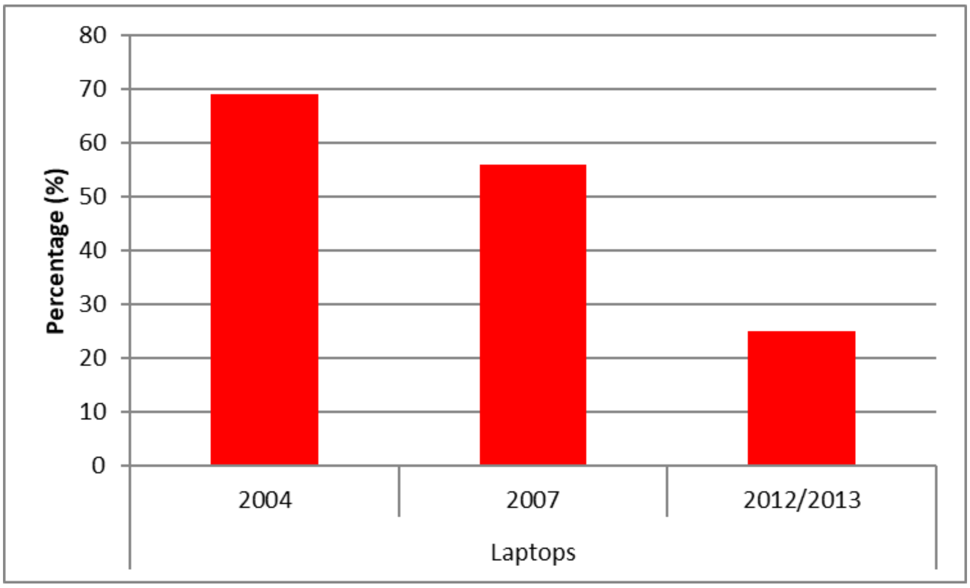
Figure 49 Average first-use period of laptops replaced primarily because "The old appliance still worked but I/we wanted a better one"



Source: Our presentation, based on GfK data (n=572 in 2012; lowest value n=169 in 2004)

However, a comparison of the data from the surveys 2004 and 2007 with the data from 2012/ 2013 shows that fewer laptops are being replaced because of the wish for a better one (Figure 50).

Figure 50 Percentage of functioning laptops that were replaced by a better one



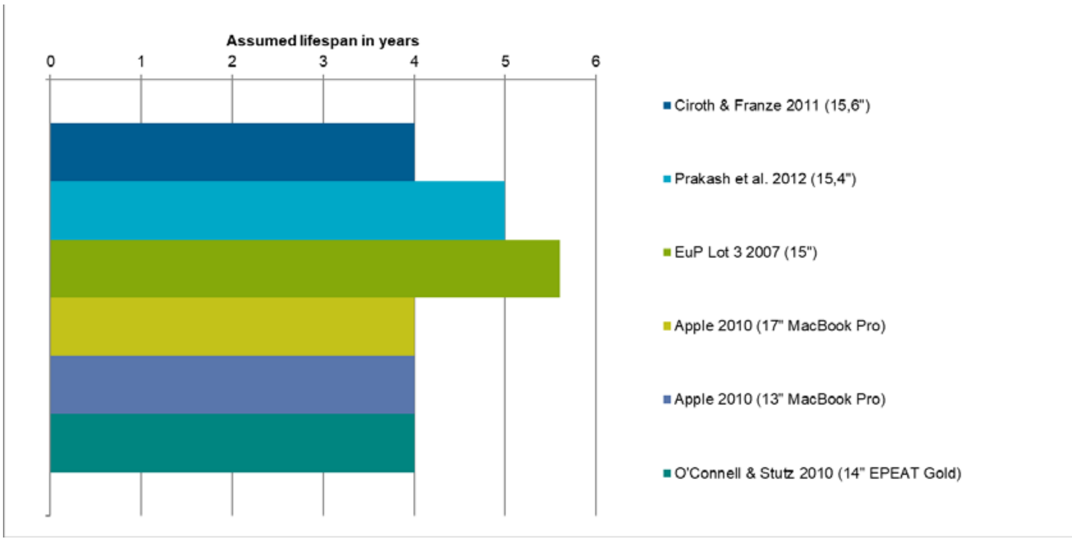
Source: Our presentation, based on GfK data

5.4.2 Evaluation of scientific studies (e.g. life-cycle assessments)

Laptops

Various assumptions are made in the literature about the lifespan of laptops. Figure 51 provides a summary of the assumptions from six recent life-cycle studies. A typical assumption is for a lifespan of 4 years (Ciroth & Franze 2011; Apple 2010; O'Connell & Stutz 2010). Other sources cite a lifespan between 4 and 6 years (Prakash et al. 2012: 5 years; IVF 2007: 5.6 years).

Figure 51 Assumed lifespans of laptops in published life-cycle assessments



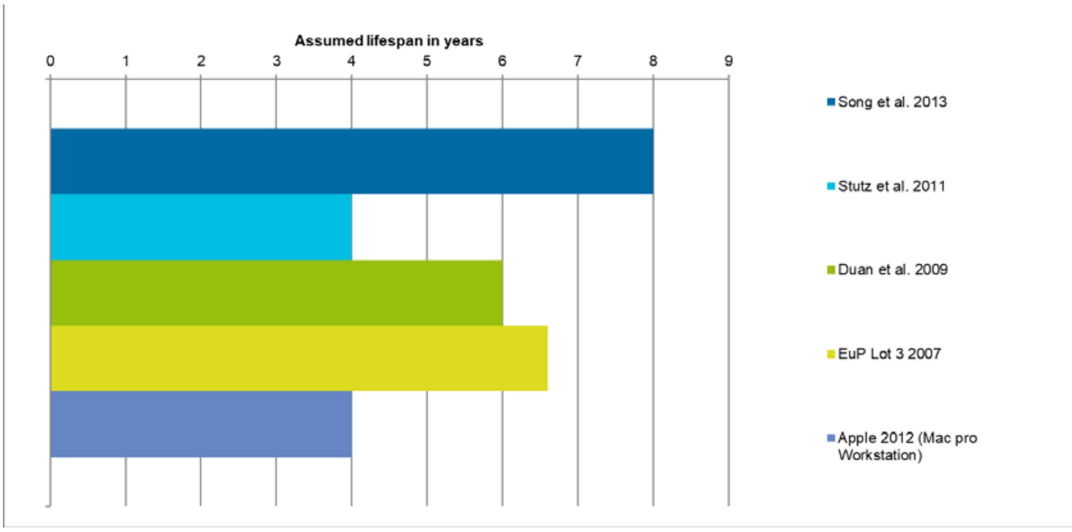
Source: JRC (2014b)

It is not possible to derive a trend for changes in lifespans (longer or shorter) from the available data.

Desktop-PCs

Different assumptions are also made in the literature about the lifespans of desktop PCs (Figure 52). Whereas Stutz et al. (2011) and Apple (2012) estimate 4 years, Duan et al. (2009) assumes 6 years, and IVF (2007) 6.6 years and Song et al. (2013) assume 8 years.

Figure 52 Assumed lifespans of Desktop-PCs in published life-cycle assessments



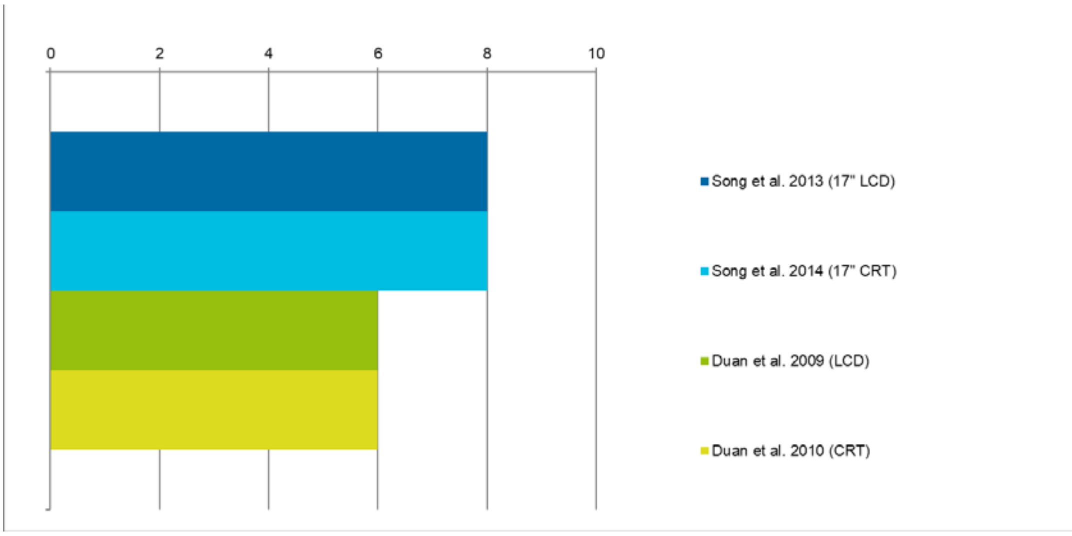
Source: JRC (2014b)

It is not possible to derive a trend for changes in lifespans of Desktop-PCs on the basis of the available data.

Computer monitors

The assumed lifespans of computer monitors in the literature are typically between 6 and 8 years.

Figure 53 Assumed lifespans of computer monitors in published life-cycle assessments



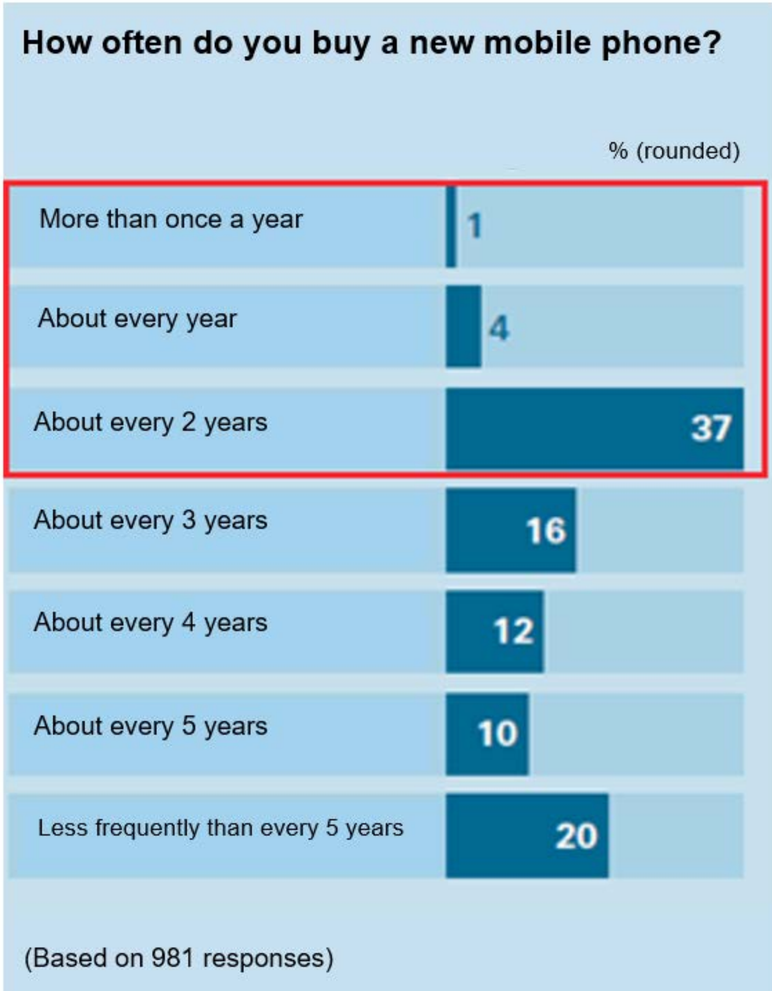
Source: JRC (2014b)

Mobile phones

Defra (2009) carried out a comprehensive study of the lifespans of products, and in the case of mobile phones assumed a lifespan of 2 years. This is confirmed by Manhart et al. (2012) for the first use of smartphones. This lifespan is connected to the fact that mobile phone contracts in Germany usually cover a 2-year period and the period of use correlates closely with the duration of the contract. When a new contract is signed, the user often acquires a new model and the old phone is taken out of service.[44] But since smartphones often find a second user, according to Manhart et al. (2012), an average use period of 2.5 years can be deduced.

According to a survey by Stiftung Warentest (2013) some 42% of users in Germany replace their mobile phone within 2 years (Figure 54). Some 16% of users replace their phone every 3 years, a further 12% every 4 years. Only about 20% of interviewees replaced their mobile phone less frequently than every five years.

Figure 54 Frequency or replacing mobile phones in Germany



Based on: test 9/2013, Stiftung Warentest (2013)

Investigations in Japan for the years 1995–2007 (Murakami et al. 2010, see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**) also show that the average lifespan for mobile phones is between 2 and 2.9 years.

[44] Some mobile phone service providers in Germany were advertising for new customers in 2014 by offering a new smart phone every year.

6 Systematic review of the causes of obsolescence

6.1 Backround

In Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** it was shown that there has been a decrease in the period of first use for televisions in particular, and that the proportion of large domestic appliances replaced because of a defect within five years increased from 3.5 % in 2004 to 8.3 % in 2012.

In this chapter, typical factors, features, and components are identified which lead to the end of the period of use. In the context of material and functional obsolescence, the influence on the lifespan of safety-relevant measures (weak points or software programming) is investigated. The aim is to be able to distinguish such influences from material and functional obsolescence. If wear parts or programmed solutions are integrated in appliances, then the access for and ease of repairs was considered, as well as the availability of professional repair services and spare parts and options for software updates. In connection with the repair measures, economic obsolescence was scrutinised, i.e. costs of repairs were compared with the purchase price of new alternatives. Psychological obsolescence was described for relevant product groups identified in Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** (e.g. televisions and smartphones).

6.1.1 Evaluation of scientific studies and independent product tests

In order to determine factors limiting the operating life in terms of material, psychological, functional and economic obsolescence, as a first step scientific studies and independent product tests evaluated, drawing for washing machines on the lifespan tests conducted by the consumer association Stiftung Warentest (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**). In these tests, problems were identified that limited the lifespan of washing machines. For other product groups, such as electric toothbrushes, espresso machines, steam irons, hand mixers, vacuum cleaners, etc., reference was also made to product tests of Stiftung Warentest.

Relatively few scientific studies have systematically addressed the possible causes of defects in various products. The British institute WRAP[45] cooperated with manufacturers, repair businesses and dealers in a systematic review for a series of product groups, including washing machines, televisions and laptops. The WRAP-studies were therefore used for the first analysis of the causes of defects.

For smartphones/mobile phones, the online repair platform “http://www.ifixit.com” was evaluated. This makes detailed repair instructions for electrical and electronic appliances available online, with short YouTube videos, so that end users can repair devices themselves, in some cases requiring appropriate special tools. The statistics on the number of viewers of such repair instructions and feedback about how many corresponding components had been successfully repaired are made accessible by ifixit.com without charge. Conclusions could be drawn from these figures about the frequencies of various defects making repairs necessary.

6.1.2 Expert survey

On the basis of the evaluation of the scientific studies and the product tests, experts were contacted and a survey carried out.

[45] Waste & Resources Action Programme; http://www.wrap.org.uk/

In February/March 2014, a total of 68 experts were sent a written questionnaire by e-mail, including appliance manufacturers, test institutes, repair and re-use operators, academic institutions working on material sciences and design, standards institutions, and consumer organisations (questionnaire and list of addressees: see Annexes I and II, p. 303 f). In addition, telephone conversations and meetings were carried out with selected individuals.

The overall return rate for the questionnaire was 25%, although there were noticeable differences between the manufacturers of the individual product groups: for large domestic appliances, the return rate was 75%, which is relatively high, whereas the return rate from manufacturers of consumer electronics and ICT was only 30%. In addition to the number of the returned questionnaires, the usefulness of the data provided also played a role. Few manufacturers provided data and information that was helpful for the study and could be followed up in detail in discussion with the same manufacturer. For example, in the fields of information and communications technologies and consumer electronics many avoided answering with reference to a need for confidentiality, so that in these cases the manufacturer survey could not provide substantial data and information for further analysis.

The reluctance shown by the manufacturers is attributable to the fact that the topic of obsolescence is discussed very emotionally in the public realm and the media. Manufacturers are accused of intentionally shortening the lifespan of their products so that consumers would buy a new product sooner. One manufacturer summarises that:

> *“[…] the entry of details in a questionnaire on “obsolescence” could automatically be regarded as a confession of dealing with planned obsolescence. I find this whole topic extremely difficult because in the final analysis every product could be accused of planned obsolescence, because all material goods are affected by some form of wear. In other words it is always a question of definition”*

Other manufacturers argued that intentionally placing lower quality products on the market would be a misguided company strategy. In a competitive market it would mean that consumers would be dissatisfied with the company’s products and as a consequence would switch to products of competitors. One company replied as follows:

> *“[…] We try with all the means at our disposal to construct appliances with a long life, in order to achieve customer loyalty to our brand. Only if customers are satisfied with their appliance and above all with the service offered to them will they stay with this brand. If there are failures, then we try to find a good solution in each service case. We provide a technical hotline for service companies and dealers in order to support repairs and reduce costs for the end-customer. Please understand that no comments can be made about failure rates and repair costs, because these are internal.”*

A further manufacturer argued in a similar vein:

> *“[…] Question 1.8 implies that our engineers were not doing a good job in the design of appliances. Our products are constructed for a long life. We are not able to answer Question 2.3 because we always strive to use the best components. In this question too the questioner assumes that the manufacturers intentionally choose cheaper components with shorter lives. This is not the case and we reject this completely.*

In particular Points 2 and 3 have generated considerable wonderment among us and seem to us to indicate a political dimension that has no place in such a topic. The company (anonymous) as an established, […] globally active manufacturer of (anonymous) with experience over more than (anonymous) years, cannot allow itself to use inferior components or even to include weak points in the construction. Our end-customers and trading partners would quite rightly punish this immediately."

In view of the reluctance shown by the majority of manufacturers to make information available about design principles, causes of faults, the likelihood of failures, the design and testing of lifespans, and supplier management, it was not possible to ensure that manufacturers data was representative. The few manufacturers who did provide usable data and information gave an overview of product management in their sector, but this cannot be assumed to be representative for all manufacturers. Additional data and information about the causes of defects and the likelihood of failures was gathered from the literature, interviews with independent experts, a survey of repair services, an evaluation of duration tests carried out by the consumer association Stiftung Warentest, and also a small-scale investigation we carried out on discarded hand mixers and electric kettles. For televisions, three repair services took part, and for laptops/printers six repair services.

6.1.3 Investigations at local authority waste collection points and specialised recycling plants

In a project on the technology and sustainability of food-processing appliances, students at the University of Bonn collected discarded hand mixers and electric kettles from local waste collection points and then attempted to identify the reasons why they had been disposed of. In all, 23 hand mixers and 28 electric kettles were collected from the RSAG-disposal plant Troisdorf in late 2013/early 2014 and investigated in the laboratories of the household technology section of the University of Bonn.

6.1.4 Internet-based consumer survey

In April 2014, the University of Bonn, Institute of Agricultural Engineering, Household and Appliance Technology section, presented the study "*Statistical analysis of an internet-based survey on the obsolescence of household appliances and food processing small appliances*" (Hennies and Stamminger 2014). The aim was to identify and characterise the causes of the obsolescence of various appliances in private households. Consumer behaviour and the occurrence of obsolescence was studied in terms of the age of an appliance, price, frequency of use, defects, reason for disposal, and satisfaction. In the following the methodology is presented; the results of the consumer survey are included in the sections on the specific appliances.

6.1.4.1 Study procedure

The study cover five types of domestic appliances: washing machines, laptops, electric kettles, televisions, and hand mixers. In order to test hypotheses on obsolescence, a catalogue of questions was developed, programmed with the internet-based software SoSciSurvey and from 01.12.2013 to 06.04.2014 the questionnaire was made available online.

Participants were recruited through various channels: The Press Office of the University of Bonn issued a press release and a posting on Facebook. Research staff notified relatives, friends and acquaintances. A newspaper article and a news item about the university chair also publicised the link to the website.

6.1.4.2 Data collection and inclusion criteria

In total, 1295 responses were received from participants who said that at the time of the survey they had disposed of at least one of the relevant appliances.

The study was divided into five sub-sections for the appliances: washing machine, laptop, electric kettle, television, and hand mixer.

Of 1,295 participants, 185 participants had incomplete responses. A control question was included in order to exclude respondents who merely clicked through the questions without answering them properly. Of the 1,110 who completed the questionnaire, 952 answered the control question consistently. A single inconsistency in the control question was noted for 123 participants. A further 28 participants had two inconsistencies, three participants had 3 inconsistencies, and four participants had five inconsistencies.

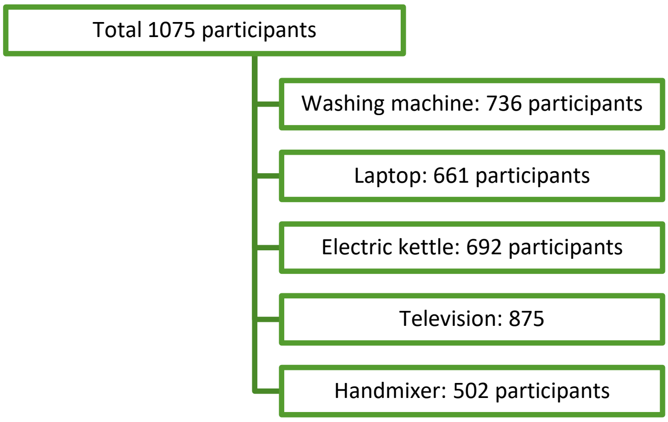
1,075 questionnaires from those participants with no more than one inconsistency in the control question were included for the calculations.

Only participants who had disposed of at least one appliance in a category were asked to answer the associated questions (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Participants who had never disposed of one type of appliance were led directly to the next category. The numbers of participants in each case are shown in Figure 55. Participants were instructed explicitly to refer in their answers to the last appliance they had disposed of.

Table 13 Numbers of appliances disposed of

Number of appliances disposed of					
Number	Washing machine	Laptop	Electric kettle	Television	Hand mixer
0	337	411	381	192	568
1	309	343	318	287	294
2	244	175	208	260	133
3	96	80	99	177	46
4	47	28	30	71	15
5 and more	40	35	37	80	14
Total	1073	1072	1073	1067	1070

Figure 55 Number of participants



Source: Our presentation

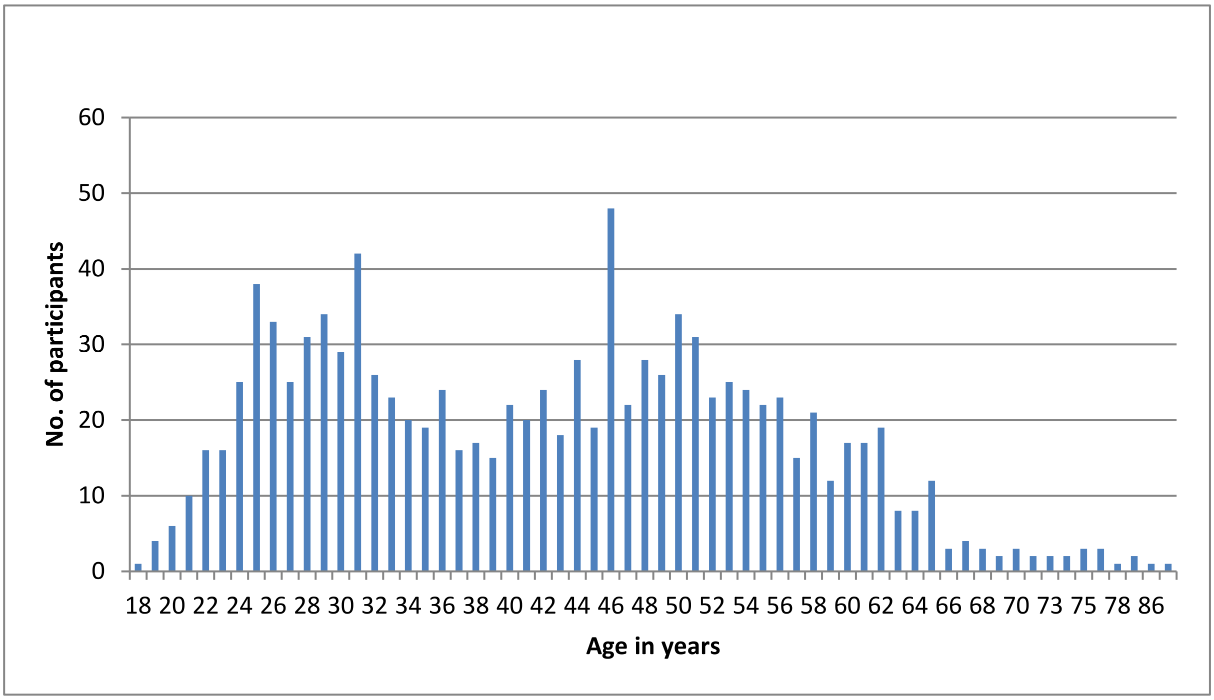
6.1.4.3 Demographics

Sociodemographic data was collected on the age, gender and income level of participants.

Age of participants

The age of 1067 participants is known (1067 of 1075; 99.3%). They were between 18 and 86 years old, with a mean age of 41.1 (± 13.2) years, and a median of 41.0 years. The age distribution is shown in Figure 56.

Figure 56 Age distribution of participants

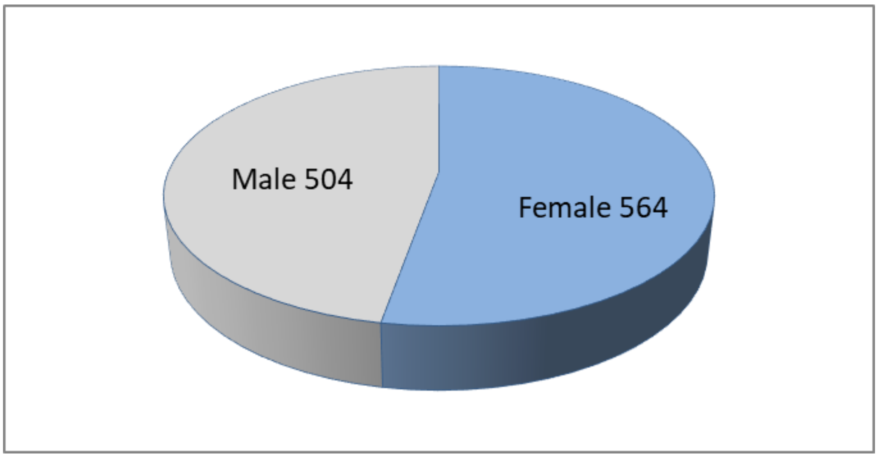


Source: Our presentation

Gender

A total of 1,068 of 1,075 participants (99.3%) responded to the question about gender (see Figure 57).

Figure 57 Gender distribution of participants



Source: Our presentation

Income

A total of 1,068 participants (1,068 from 1,075; 99.3%) answered the question about income, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. Most participants were at least fairly well off.

Table 14 Income distribution of participants

Which statement is most appropriate for you?	No.	%
I can't make ends meet	14	1.3
I just manage to get by	109	10.1
On the whole I am doing alright	431	40.1
I am well off and can afford a few things	458	42.6
I am not financially limited in any way	56	5.2
Total	1068	99.3

6.1.4.4 Statistical methodology

All the variables in the data survey were described in terms of their frequency distribution or their statistical parameters (mean, standard deviation, median, extrema of the central value). The sequence of presentation is based on the structure of the questionnaire. The p-values are based on a (double-sided) significance level of 5%. Confidence intervals were 95%. Data were not tested for normal distributions. For metric data, the Mann-Whitney U-Test or the Kruskal-Wallis H-Test was applied; frequency distributions of ordinal or nominal data were evaluated using Chi^2 tests. The p-values are rounded to the third decimal. Values below 0.001 are given as "< 0.001". In tables, rounding errors in the sums of percentages are not corrected. The data was collected and registered using SoSciSurvey. The statistical evaluation was carried out using SPSS[46] for Windows; tables and graphics in the text were produced using MS-Excel and SPSS.

[46] Statistical Package for the Social Sciences (IBM)

6.2 Causal analysis – televisions

6.2.1 Material obsolescence

6.2.1.1 An example from the media: Aluminium-electrolytic capacitors

Reports in the media about planned obsolescence often raise the topic of aluminium-electrolytic capacitors, also known as e-caps. Two design factors are mentioned (Schridde et al. 2012) that considerably shorten the lifespan of e-caps:

1. Positioning the e-caps near heat sources
2. Using under-sized e-caps.

E-caps have a limited operating life and they therefore limit the period of use of an appliance in which they are installed (Albertsen 2009). The specified lifespan of various quality grades of e-caps is dependent not only on electrical stress factors such as ripple[47] but also to a large degree on the operating temperature (T_u) (**Fehler! Verweisquelle konnte nicht gefunden werden.**) and frequency. The aging process of a capacitor leads to a reduced capacitance and poorer quality due to the increased electrical resistance.

Table 15 Lifetime of electrolytic capacitors of different quality grades depending on the operating temperature

T_u	Specified lifespans of e-caps per quality grade 85 °C / 2000 h	105 °C / 2000 h	105 °C / 5000 h
105 °C	–	2000 h *(0.2 years)*	5000 h *(0.6 years)*
95 °C	–	4000 h *(0.5 years)*	10000 h *(1.1 years)*
85 °C	2000 h *(0.2 years)*	8000 h *(0.9 years)*	20000 h *(2.3 years)*
75 °C	4000 h *(0.5 years)*	16000 h *(1.8 years)*	40000 h *(4.6 years)*
65 °C	**8000 h** *(0.9 years*	**32000 h** *(3.7 years)*	**80000 h** *(9.1 years)*
55 °C	16000 h *(1.8 years)*	64000 h *(7.3 years)*	160000 h *(18.3 years)*
45 °C	32000 h *(3.7 years)*	128000 h *(14.6 years)*	320000 h *(36.5 years)*

Based on: Bicker Elektronik GmbH (2012)

The figures provided by capacitor manufacturers represent limit values for voltage and temperature, and the lifespan figures are for purposes of orientation. According to Windeck (2003), the lifespan of e-caps is highly dependent on the conditions they are exposed to. Switching power units are the most common use of e-caps, and here the electrical design influences the size of ripple currents and therefore heat generation within the e-caps.

The operating temperature depends on the operating conditions. For TVs, laptops and other compact devices, the main problem is cooling the heat-generating components (e.g. CPU, graphics card, memory, etc.). In the case of laptops, ventilation channels regularly become blocked. This leads to an increased temperature inside the laptop and all components are exposed to a higher temperature level (Re-Use Computer). At increased temperatures, the liquid electrolyte evaporates more quickly and as a result, the capacitance (C) of the e-cap is reduced

[47] Ripples are the residual periodic variations of the DC output of a power supply.

and the electrical series resistance (ESR) increases (Disch 2015). In the worst case, a short circuit within the e-cap can occur with potentially terminal consequences for the entire system (Bicker Elektronik GmbH 2012). Generally, the lifespan of e-caps is taken to follow the empirical “10 Kelvin rule” of Arrhenius – lowering the operating temperature by 10 K doubles the lifespan (Albertsen 2009). In addition, overloads can also lead to electrolyte leaks and thus to a premature failure.

At first sight, it might seem plausible to claim that e-caps are intentionally situated near heat sources so that they will fail prematurely due to overheating. However, the location of e-caps is the result of complex design considerations for electronic circuits. For example the processor requires a precisely regulated operating voltage with currents that can exceed 70 amps, as well as high switching speeds. To meet these demands, e-caps are best located as close as possible to the processor base, since then the electrical series resistance is low and the dynamic properties are improved.

Placing the e-caps far away from the processor, with long connecting wires and high frequencies, would result in a mixture of complex capacitive and inductive resistances. This would slow down the voltage control. In addition, the long wires act as antennae, emitting interfering signals within the appliance. The antenna effect would also lead to poorer EMC[48] values for the appliance. Therefore the capacitors have to be placed as close as possible to the supply pins of the switching power supply, keeping dynamic voltage fluctuations as low as possible. Stable voltages are crucial for the reliability of electronic appliances. Voltage fluctuations of > 100 mV can lead to loss of function (Disch 2015). The experts interviewed in the course of this study have confirmed that even fluctuations of 50 mV can already cause disturbances.

Placing temperature-sensitive components such as e-caps close to heat sources may seem an unsatisfactory result. However, given the technical and physical factors described above, this is necessary to ensure the functioning of the appliance. The result is a compromise reached after weighing up complex design considerations. It does not represent planned obsolescence in the sense of intentional design manipulation.

According to experts, e-caps are selected on the basis of assumptions about normal operating conditions. In many cases, insufficient consideration is given to the possibility of increased ambient and operating temperatures, for example if the ventilation system of a laptop becomes blocked or a TV set is positioned in a bookcase affording no air circulation. As a rule, higher quality e-caps (e.g. Class 105°C/2000 h) would have a longer lifespan, but according to the manufacturers they would be more expensive[49].

Whether it is worth paying more for the higher-quality e-caps in the view of product developers can be considered using a simple example. An e-cap of the quality class 105°C/2000 h at an operating temperature of 65°C will have a calculated lifespan of 32,000 hours[50]. Assuming that a TV set is in use for an average of 4 hours a day, the lifespan of the installed e-caps would be

[48] ‘Electromagnetic compatibility’ means the ability of equipment to function satisfactorily in its electro-magnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment” (Directive 2004/108/EC on electromagnetic compatibility). Since 01.01.1996 all manufacturers of electrical and electronic equipment must provide proof of the electromagnetic compatibility (EMC) of their products. It must be ensured that electrical devices do not influence one another. Products that fail to comply with the legal limits may not be sold on the European market.

[49] According to the experts interviewed in this project, the price difference between Classes 85°C/2000 h and 105°C/5000 h for a relatively small order is 10-15%. However, the general trend among e-cap-manufacturers is towards longer lifespans to meet rapidly increasing demand in the automotive sector. With less demand for standard components, these can no longer be produced as profitably.

[50] $L_x = L_{Spec.} 2^{T_o - T_u/10}$; with L_x = actual lifespan (h), $L_{Spec.}$ = specified lifespan (h), T_o = upper limit temperature (°C) and T_u = operating temperature (°C).

about 22 years. If the lifespan of the TV set is a priority, a product developer would most likely choose e-caps of the Quality Class 105°C/2000 h.

If an e-cap of Class 85°C/2000 h was used instead, it would have a lifespan of only about 5 ½ years at the same operating temperature of 65°C. Had the whole product been designed for a useful life of about 5.5 years from the start, then all the parts and components of this TV set (including the e-cap) could be chosen correspondingly, in order to optimise costs and the use of materials and resources. In this case, the product developers would argue that a Class 85°C/2000 h e-cap was most suitable from an economic point of view for the proposed application.

However, if the assumed operating temperature of 65°C were to be exceeded, this would shorten the expected lifespan of the e-caps and thus in most cases also of the TV set. For example, at an operating temperature of 75°C the expected lifespan of e-caps (Class 85°C/2000 h) is only 4,000 hours or 2.7 years. Under the same conditions, a Class 105°C/2000 h e-cap would still have a lifespan of about 11 years. This example shows that choosing the right e-cap has an important effect on the product lifespan and the use of higher quality e-caps would make good sense from an environmental point of view, despite the increased costs.

The example of Loewe Technologies, which places high demands on the lifespan of its appliances (10 years/20,000 hours), shows that it is possible to avoid the early failure of e-caps. The company says that it has no problem with premature failures, and chooses the e-caps so that under normal conditions they are operating at no more than 75% of their rating. In the development phase, internal and external heating effects are measured for critical e-caps. The aging of an e-cap leads to a reduction in capacitance and the loss of quality. Therefore, the circuits are designed to remain functional until the value of one of these two parameters falls to below 50% of the original value. Thus, the lifespan of the circuit is extended even though the e-cap is far outside its specified range and the component is in fact already defective. Using this approach, Loewe Technologies claims to have been able to extend the lifespan of its appliances at a time when there were no e-caps designed to meet the lifespan specifications (10 years or 20,000 h).

Quality deficits of e-caps can also result from their handling prior to being installed. During transport and storage, chemical processes can have negative effects on the dielectric. A common example is damage by halogens, in particular bromide, used to sterilise the components during transport overseas (Disch 2015).

According to Disch (2015), cutting or bending the connecting wires during the assembly can exert mechanical forces within the e-cap, damaging the winding or weakening the oxide coating on the anode. According to the experts, there are also other common production problems, such as the soldering of the connecting wires, dosing of the electrolyte and the electrolyte concentration.

For these reasons, it is advisable not only to set minimum requirements for e-caps and to formulate realistic operating conditions for the functional testing, but also to introduce strict quality management along the supply chain. The extra costs for the appliance manufacturers would not seem to be significant in view of the environmental benefits of the extended lifespans (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

In summary, the accusation of planned obsolescence, in the form of intentionally using undersized e-caps with the sole aim of manipulating consumers and forcing them to buy a new product, cannot be confirmed. The e-caps are chosen on the basis of economic considerations in the course of a complex product development process, taking into consideration the expected lifespan and use of the product. Products are designed so that all their parts and components have more or less the same lifespan, allowing the cost-effective use of resources.

6.2.1.2 Literature review

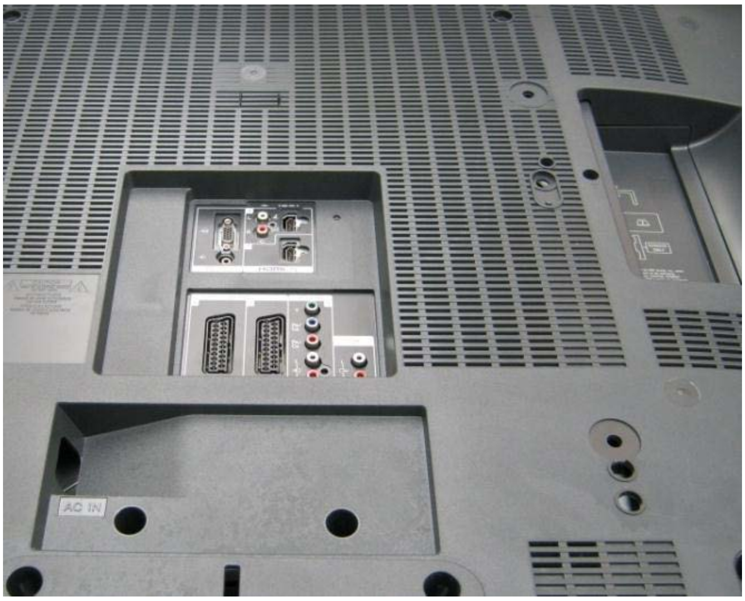
WRAP analysis: The British WRAP research institute published a product design review in 2011 on the material weak points of LCD-TVs (WRAP 2011a)[51]. The results are summarised here. WRAP drew of an extensive survey of the repair industry and identified the following reasons why the lifespan of LCD televisions is shortened, as well as design options that could reduce the frequency of such defects.

Insufficient mechanical robustness

Although televisions are not normally designed for mobile use, components can be damaged by mechanical effects during the transport of the appliance. This relates mostly to fragile parts such as the screen. The robustness of the housing is clearly a critical factor for the durability of the appliance.

Interfaces, sockets, on-off switches and function switches are better protected against damage if they are installed in a rigid housing. They should also be placed at a sufficient distance from vulnerable points (e.g. away from the corners of the appliance). Sockets and ports can be best protected against mechanical impacts if they are positioned in recesses in the housing (cf. Figure 58).

Figure 58 Recessed positioning of ports and sockets to protect them against mechanical impacts



Source: WRAP (2011a)[51]

Strengthening the housing with steel elements or by robust polycarbonate/acrylonitrile butadiene styrene (PC/ABS) reduces the likelihood of damage to the appliance during transport. Conversely, a lack of strengthening can make it more likely that mechanical impacts can damage the appliance and lead to the end of its operating life.

[51] From the website www.wrap.org.uk of the Waste and Resources Action Programme.

Figure 59 Poor attachment of the stand of a TV set with screws

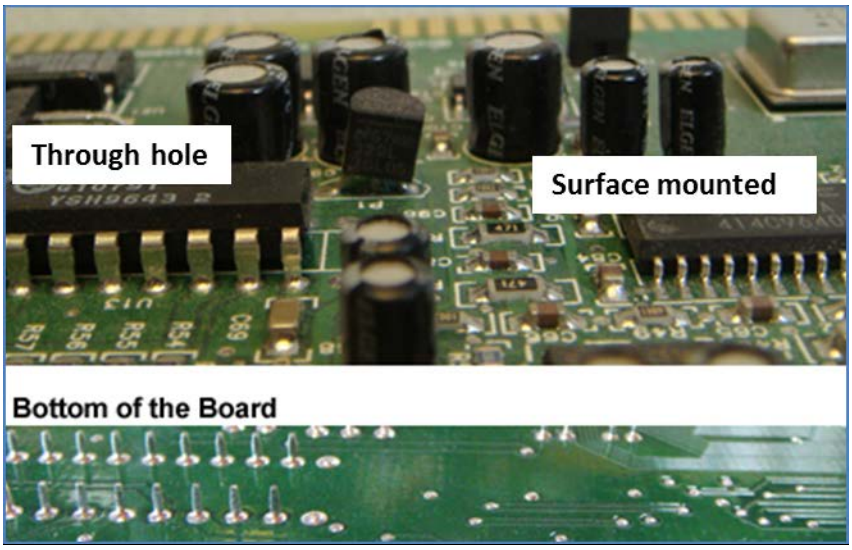
Source: WRAP (2011a)[51]

The mechanical stability of the stand is important for the lifespan of TVs, because if the set falls over the damage to the screen is frequently irreparable. Fixed attachment of the TV stand directly with the housing / chassis provides good stability. Loose connections between stand and housing, for example by means of screws, are less robust (cf. Figure 59).

Insufficiently robust electronics

According to WRAP (2011a), the poor stabilisation of the PCBs by the housing is a frequent cause of defective electrical connections. In this context, WRAP (2011a) also reports that surface-mount technology (SMT) is much less susceptible to faults than through-hole mounting (cf. Figure 60).

Figure 60 Through-hole soldered connections (left) compared with surface-mounted connections (right)



Source: http://encyclopedia2.thefreedictionary.com/thru-hole

Inadequate heat sinks can lead to overheating and the failure of components (see Section 6.2.1.1 on aluminium-electrolytic capacitors). This is particularly important for TVs, which in contrast to computers do not have ventilators to cool the electronics.

Finally, knock-on effects can be critical for the lifespan. For example, a fault in the power supply should not lead to a defect on the main board. Sufficient electronic protection can be provided if the components are separated spatially (WRAP 2011a).

Poor technical support and lack of access to spare parts

Regarding repairs, impediments are typically encountered if manufacturers do not provide technical support beyond the warranty period, or offer no FAQs or trouble-shooting tips and (online) repair instructions.

The repair of televisions is also made difficult if spare parts are extremely expensive or are not available, possibly as a result of the rapid succession of models. WRAP 2011a reports that the key problem in this context is the replacement of the LC displays. The replacement parts are so expensive that a cost-effective repair (in this case in Great Britain) is not possible.

Obstacles to repairs

Parts of the housing are often stuck together, so that it is difficult to get to the “insides” of the device without causing damage. In addition, the use of special screws can present a problem, and some screw connections are hard to find.

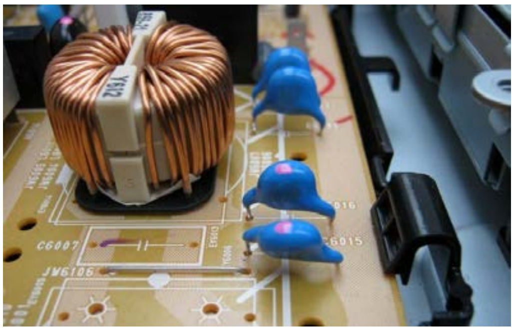
Accessing circuit boards, e.g. the graphics card, is difficult in some cases. Ease of access would simplify repair work and thus increase the chances of a longer period of use. When connections between circuit boards are soldered, this too makes repairs difficult. Plug-in connections make it possible to replace individual components (cf. Figure 61).

Figure 61 Plug-in connections between circuit boards

Source: WRAP (2011a)[51]

The use of clip connections instead of screws (cf. Figure 62) simplifies repairs, and colour coding of components can help to identify components for repairs. In addition, colour-coded components and plastic polymers can be identified more quickly for recycling.

Figure 62 Clip connections instead of screws for PCBs



Source: WRAP (2011a)[51]

6.2.1.3 Expert interviews

In the expert interviews, only a few manufacturers of consumer electronics supplied relevant data about the possible causes of obsolescence (see Section 6.1.1). The following information and data are therefore not representative.

An evaluation of the expert interviews regarding the causes of obsolescence in televisions shows that most of the parts and components we asked about rarely fail. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the average likelihood of failure according to Loewe Technologies. It should be noted that not all the components fail during this period in any single appliance.

Most faults in televisions are software related (functional obsolescence, see Section 6.2.2). The most likely hardware-related causes of failure for a television are a defect of the display (<3%) or the hard drive (<3%). This is followed by the power supply card (<2%) or the main board (<1.5%). For the other parts and components, the likelihood of failure is already less than 1%: Loudspeakers fail in fewer than 0.4% of cases, aluminium-electrolytic capacitors in fewer than 0.3% of all cases, interfaces and soldered connections less than 0.2%. (These conclusions are based on information from one manufacturer and are therefore not representative.)

Table 16 Quantitative reports on likelihood of failure for TVs (Loewe Technologies, 2015)

Parts/components	Likelihood of failure			
	Never	Rarely	Often	Very often
Display /Monitor unit		X<3%*		
Power supply card		X<2%*		
Main board		X<1.5%*		
Loudspeakers		X<0.4%*		
Aluminium electrolytic capacitors		X<0.3%*		
Interfaces/ sockets		X<0.2%*		
Soldered connections		X<0.2%*		
Housing		X<0.1%*		
Switch		X<0.1%*		

Parts/components	Likelihood of failure			
	Never	Rarely	Often	Very often
Stand		X<0.1%*		
Plug-in connections		X<0.1%*		
Screws	X			
Others: _____hard drives		X<3%*		
Note: The main source of faults for TVs are software bugs (see Section 6.2.2)				
* Assumed operating life: 5 years; 5h/ day= 10,000 hours				

Additional qualitative comments on the likelihood of failure were provided. For example, it was pointed out that damage to the housing only occurs during transport. Manufacturers exclude the possibility of defective screws.

In addition, the following reasons were given for the failure of components:

- Power supply: mainly due to defective electrolytic capacitors (e-caps);
- Faults during assembly;
- Soldering faults for Ball Grid Arrays[52];
- Cable customisation errors;
- Software errors;
- Less often: component failure, housing damage (only as transport damage);
- Hard drive: after 5 years operation, the main cause of faults is wear.

As a rule, manufacturers plan the lifespan of their products in detail (Primus 2015). According to Woidasky (2015), they begin with a product idea or a specific market demand and develop a detailed requirement catalogue which serves as the basis for the development process. This also takes into account internal requirements, and market and societal considerations, including information about competing products and the legislative framework.

Loewe Technologies develops TVs to have a lifespan of 10 years, based on an average operating time of 20 000 hours (use of 5 hours per day), with 100 000 hours on stand-by. Loewe Technologies sets the following requirement criterion: within 20 000 hours, no individual component should have a failure rate of more than 10%. This criterion is tested by means of an accelerated long-term life test at elevated temperatures with more than 20 appliances.

[52] A ball grid array (BGA) is used to mount devices for integrated circuits, presenting fewer problems at high densities, less risk of overheating, and lower lead inductance. However, since the solder balls cannot flex, thermal stresses or vibrations can cause joint fractures, and once the package is soldered in place it is difficult to identify soldering faults.

It can be assumed that the other manufacturers also design their TVs for a specific lifespan. However, none of them were willing to provide comparable details. In this respect, the openness and transparency of Loewe Technologies was commendable.

Expert interviews were also conducted with three repair companies, who provided information on the basis of many years of practical experience. Nevertheless, the information provided cannot be regarded as representative of all repair companies.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the likelihood of defects of individual components in televisions as reported by one of the repair businesses. However, these are not comparable with the entries in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The responses of the repair shops are qualitative and do not specify the age of the appliances at the time of the repair. More research is required here, and a differentiation of the repairs in terms of parts and components would also be desirable.

Table 17 Reply of a repair shop about the likelihood of TV defects

Component	Likelihood of a defect			
	Never	Rarely	Often	Very often
Housing	X			
Switches		X		
Interfaces/connections		X		
Stand	X			
Display/monitor unit			X	
Plug connections	X			
Aluminium-electrolytic capacitors				X
Soldered connections		X		
Power supply card				X
Mainboard		X		
Loudspeakers		X		
Screws	X			
Others: ___________________________				

The responses of the other two repair companies conform with the details shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

In summary, the responses of the manufacturers and the repair company, as well as the results of the WRAP analysis confirm that the parts and components limiting the lifespan are the display/monitor unit, power supply card, aluminium-electrolytic capacitors, and damage to sensitive components during transport. These are therefore the main causes of material obsolescence.

6.2.1.4 Results of the internet-based consumer survey

Responses are included from the 875 participants of the consumer survey who had recently disposed of a television.

Television purchased new or second-hand

76 % of the discarded televisions had been bought new, 23 % second-hand (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 18 Television originally purchased new or second-hand

Was the television new when you bought it or second-hand?	Frequency	%
New	666	76.1
Second-hand	201	23.0
I don't know.	8	0.9
Total	875	100.0

Age of the television[53]

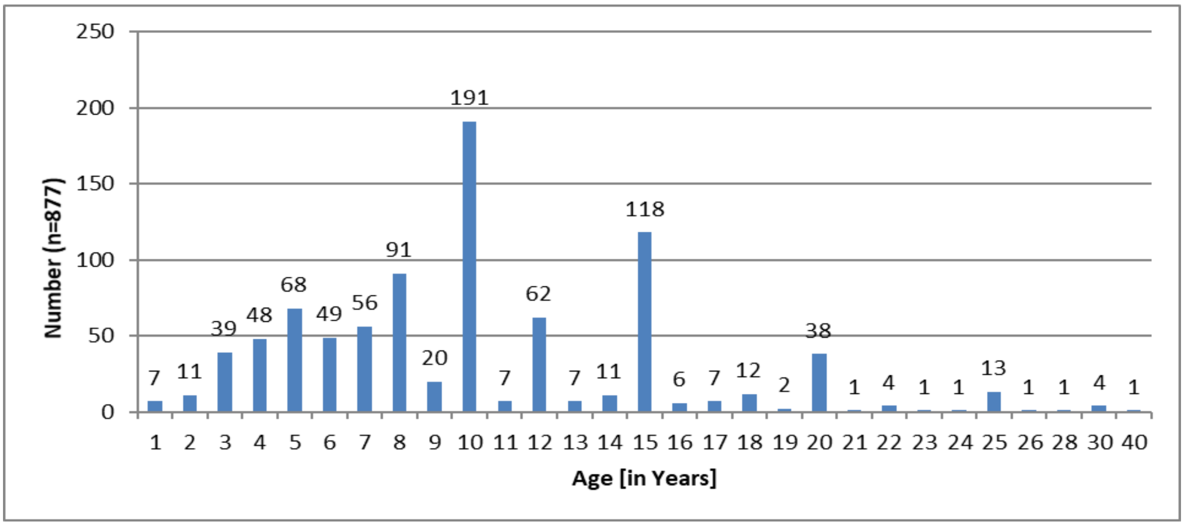
50 % of the discarded televisions were 10 years old or less (**Fehler! Verweisquelle konnte nicht gefunden werden.**). In Figure 63 there are noticeable spikes in the "round" years (10, 15, 20,25), which was also observed for other appliances

Table 19 Age of the television

How old was your old television? If you do not know then please estimate a value [in years].								
N	Mean	SD.	Min.	Max.	25th percentile	Median	75th percentile	Range
877	10.2	5.2	1	40	6	10	14	39

[53] In the survey, no distinction was made between CRT televisions and flat-screen appliances. But according to the analyses in Section **Fehler! Verweisquelle konnte nicht gefunden werden.** they have very different first-use periods. It can be assumed that a relevant proportion of responses in the Internet survey still relate to tube televisions.

Figure 63 Age of television



Source: Our presentation

Price of the television

44 % of the discarded televisions medium-priced appliances. Just over 20 % each were inexpensive appliances or expensive appliances (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 20 Price of the television

How expensive was this television?	Frequency	%
An inexpensive appliance (no-name brand)	184	21.0
A medium-priced appliance	385	43.9
An expensive appliance (top brand)	189	21.6
I don’t know.	118	13.5
Total	876	100.0

Repair of the television

23 % of the televisions had been repaired (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Of these, 17 % were repairs under warranty; 77 % of the repairs were carried out after the warranty had expired (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 21 Repair of the television

Had this television ever been repaired?	Frequency	%
Yes	198	22.5
No	626	71.2
I don’t know	55	6.3
Total	879	100.0

Table 22 Repair under warranty – television

Was the repair carried out in the warranty period?	Frequency	%
The repair was carried out in the warranty period.	34	17.4
The repair was carried out after the warranty had expired.	150	76.9
I don't know	11	5.6
Total	195	100.0

Frequency of use of the television

Nearly all participants said that their television had been used several times a day, daily, or several times a week (together 96.7 %), rarely less frequently (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 23 Use of the television

How frequently have you used this television as a rule? If you do not know exactly, please estimate a value	Frequency	%
Almost never	5	0.6
Once a month	6	0.7
Once a week	18	2.1
Several times a week	179	20.4
Daily	457	52.1
Several times a day	212	24.2
Total	877	100.0

Fate of the television

54 % of the televisions had been finally disposed of, 33 % were passed on, and 12 % were kept (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 24 Fate of the television

What did you do with the old television?	Frequency	%
Disposal	476	54.4
Passed it on (sold, given away)	284	32.5
Kept it	104	11.9
Some other option	11	1.3
Total	875	100.0

Reason for buying a new television

44 % of the old televisions had been disposed of due to a defect. But this implies that 56% of appliances were replaced although they may still have been in working order (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 25 Reason for buying a new television

Why did you get rid of the television? Choose the most appropriate reason	Frequency	%
The television was defective	381	43.5
I didn’t like the television any more	140	16.0
The television didn’t have enough functions	137	15.7
I was given a new television	67	7.7
I had some other reason	129	14.7
The television used too much electricity.	21	2.4
Total	875	100.0

Satisfaction with the lifespan the television

Fehler! Verweisquelle konnte nicht gefunden werden. shows the satisfaction with the lifespan of the television; in all 16 % were not satisfied with the lifespan of their TV set.

Table 26 Satisfaction with the lifespan of the television

How satisfied were you with the lifespan of this television?	Frequency	%
The lifespan met my expectations	381	43.4
I was surprised how long the old television kept working.	138	15.7
It was time to replace the television with a new one	189	21.5
I expected it to last longer	94	10.7
The television only worked for much too short a time.	50	5.7
I don’t know.	26	3.0
Total	878	100.0

Defect of the television

The most common defects of televisions according to participants affected CRT tubes and the electrics (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 27 Defect of the televisions

What exactly was wrong with the television?	Frequency	%
Tube	136	35.7
Screen	71	18.6
Switch	26	6.8
Electrics	134	35.2

What exactly was wrong with the television?	Frequency	%
Another fault	27	7.1
I don't know	72	18.9
Total number of responses	466	122.3
Total number of participants	381	100.0

6.2.2 Functional obsolescence

In this section, the role of functional factors is considered with regard to the lifespan and duration of use of televisions. In this context, it seems reasonable to distinguish between the following types of factors:

- factors outside the sphere of influence of the TV manufacturer
- factors within the sphere of influence of the TV manufacturer

Functional factors within the sphere of influence of the TV manufacturer

Lack of error diagnosis function

For the repair of TVs, a so-called error diagnosis function is very useful. In addition, a memory card can store information for repairers that can be accessed via an extra interface. The interface can also be used to install relevant updates, which will also extend the lifespan of the television (see also Section 6.2.1.2).

Figure 64 Interface for reading out information for repairs or for updating the software

Source: WRAP (2011a)[51]

Functional factors outside the sphere of influence of the TV manufacturer

New formats

TV-formats have progressed through the following stages:

- Standard Definition (SD)
- High Definition Ready (1280 x 720 pixel)
- Full-HD (1920 x 1080 pixel)

- Ultra High Definition (3840 x 2160 pixel)

The rapid development of the standards in recent years has meant that the hardware chips in older appliances (transmitter and receiver chips) are not able to read out the relevant newer formats. HDMI 1.4 connections are able to transmit 30 frames per second. The HDMI 2.0 connection offers a 60 Hz transmission rate. The intention is that TVs will be able in future to receive 60 Hz Ultra-HD signals. According to the computer magazine c't (2013), however, the HDMI receiver chip in the TV set would have to be capable of processing the corresponding bandwidth. But while the HDMI specification for 60 frames per second in UHD requires some 18 GBit/s, an upper limit of 10.2 GBit/s is specified in the HDMI 1.4 version.

According to the computer magazine CHIP (2014), some manufacturers offer the opportunity to retrofit their UHD-TVs with HDMI 2.0 by hardware update[54]. Others offer firmware updates to convert HDMI-1.4 interfaces to the 2.0 standard. However, the lack of bandwidth of the chips will probably lead to a loss of quality when presenting UHD transmissions.

New functions

The new functions being offered, such as HbbTV[55], Internet radio, streaming, etc., place great demands on the software. A TV manufacturer reports that the current trend towards Smart TVs[56] presents considerable challenges. Televisions can be compared with high-performance multimedia computers (high-performance graphics cards, sound cards, internet connectivity, etc.). If the software of an older TV set is not modular and the TV set does not have a scalable memory, then it would soon reach its limits when dealing with new contents and functions.

New transmission standards

The switch from analogue to digital television did not lead to a unification of transmission standards. Rather, various standards now exist in parallel. For example, there are three systems for terrestrial HDTV transmission systems: ATSC[57], DVB-T[58] and ISDB-T[59].

Network providers set their own specific transmission standards. There are various standards in Europe (e.g. NorDig Spec[60]), and even within Germany different network providers may have different formats. This can mean that a TV set that works in Munich might have to be converted before it can be used in Cologne.

One factor is that different network providers allocate channels differently, so that a new scan is required whenever the location is changed. Each manufacturer sets their own standard for Dynamic Channel Management, and the regional differences can lead to problems when searching for channels in another network setting.

[54] For example, Samsung offers an Evolution Kit for up-dating hardware and software capacities of Smart TVs. It is plugged into a socket at the back of the TV set and is automatically integrated by software. The technical datasheets of Samsung mention that "the up-dates of the Evolution Kit are limited to the year of publication and the availability of the relevant applications. The performance can vary and depends on model specifications and hardware limitations. Some contents, TV services and functions may not be available in all regions and countries." (SAMSUNG 2014).

[55] HbbTV (Hybrid Broadcast Broadband) is a standard for Hybrid-TV, which combines broadcasting, IPTV and broadband internet can offer new information and services.

[56] Smart TVs have additional computer functions such as Internet connectivity, and interfaces for USB, WLAN, and memory cards.

[57] Advanced Television System Committee establishes standards for digital televisions, including high-resolution TVs. It is the North American equivalent of the DVB-T standard.

[58] Digital Video Broadcasting – Terrestrial: DVB-T is a variant of the digital video transmission, used for the terrestrial transmission of digital radio and television signals.

[59] Integrated Service Digital Broadcasting - Terrestrial is an MPEG-2 based standard for terrestrial digital media transmissions.

[60] Nordic Broadcast Specifications; http://www.nordig.org/pdf/NorDig-Unified_ver_2.4.pdf

Conditional Access (CA) systems[61] can also make it more difficult to switch from one network provider to another when each provider encodes transmissions according to their own rules.

It would be helpful if an opportunity was provided for the conversion of the conditional access, e.g. by means of an appropriate slot. Some manufacturers guarantee the possibility to exchange a slot. However, if a manufacturer does not do this then televisions may only be usable in one region, limiting the use of the set after moving to another region.
Since the demands on TVs are growing, it can be advantageous if a scalable memory is installed, so that additional software can be loaded at any time.
Close technical links of operating system and hardware can mean that the lifespan of the software necessarily determines the lifespan of the hardware. According to one of the manufacturers, this is the case in particular if the software is not modular and portable. A manufacturer reports using software with layer structures that can in principle be used on any hardware platform. It is only necessary to adapt the HAL (Application layer) to the new hardware. This allows a rapid transfer of the software functionality and graphical user interface (GUI[62]) to a new hardware. The basic idea of modular software with horizontal partitioning is that it can be reused for appliances of following generations. The main advantage is that it does not have to be tested again.

Increased quantities of source code

In recent years there has been an increase in the source code for Smart TVs from 1 MB to more than 100 MB, so that testing the entire source code for errors can now take up to 15 working weeks. Given the very short product innovation cycles (cycle length 1 year), in many cases the source code is only tested for typical faults and the likelihood of failures is determined using statistical regression methods. The tests focus on internet connectivity, WLAN connections, Bluetooth, and the networking to routers. Some manufacturers reduce the test time in this way to about 3 weeks. However, the functionality of the entire software has not been tested so that there may still be software errors.

If Smart-TVs are to have a long lifespan it is important that their software is regularly maintained. This includes functional improvements and new functions (e.g. DLNA renderer[63] for compatibility of appliances from different manufacturers). One manufacturer reports that the software of appliances should be updated as far as the hardware allows in order to avoid future functional limitations. These regular software updates would make new functions possible or would remove limitations as the market develops further. An Internet would be required and registration with the manufacturer.
Under these conditions a TV manufacturer judges that from a functional perspective a fault-free operating period of 5 years would be realistic. Without an Internet connection and with no updates, functions could be limited sooner or would be faulty.

6.2.3 Psychological obsolescence

In Section **Fehler! Verweisquelle konnte nicht gefunden werden.** it was shown that the innovation cycles have shortened dramatically since the introduction of flat-screen TVs. Innovations determine the duration of first-use and the wish for an even better, more innovative

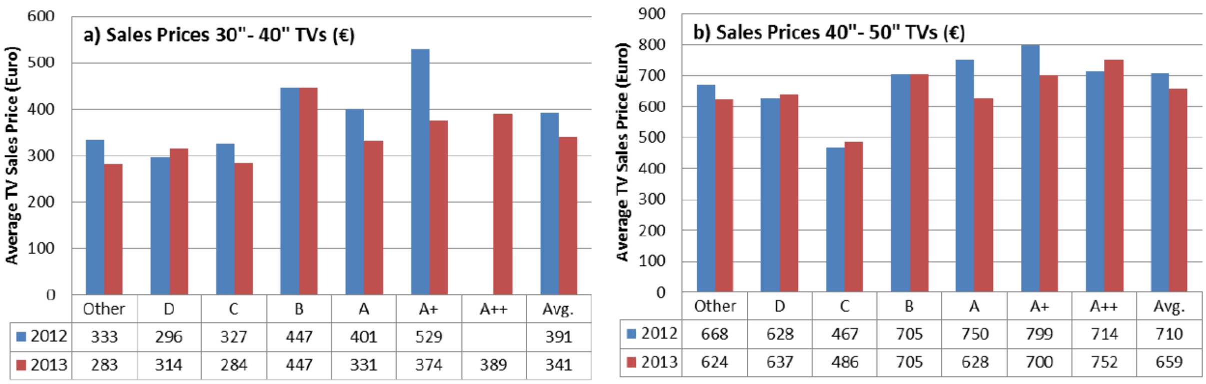
[61] Conditional Access is the system used for encrypting programme contents for Pay TV. A conditional access module (CAM) is an electronic device, usually incorporating a slot for a smart card, which equips an Integrated Digital Television or set-top box with the appropriate hardware facility to view conditional access content (Wikipedia).

[62] The graphical interface use is the interface of a computer used via graphic symbols (e.g. via mouse or touch screen).

[63] DLNA (Digital Living Network Alliance) was founded by a group of consumer electronics companies to develop and promote interoperability guidelines for sharing digital media between multimedia devices.

appliance. According to Loewe Technologies, an innovation cycle in the TV industry is now only 1 year. Along with these extremely short cycles, the prices of TVs are also falling according to CLASP (2014), as Figure 65 shows:

Figure 65 Average sales prices of TVs according to energy efficiency class in EU-24



	Other	D	C	B	A	A+	A++	Avg.
2012	333	296	327	447	401	529		391
2013	283	314	284	447	331	374	389	341

	Other	D	C	B	A	A+	A++	Avg.
2012	668	628	467	705	750	799	714	710
2013	624	637	486	705	628	700	752	659

Source: CLASP (2014), based on GfK-data

As Figure 65 shows, in EU-24 the average price of a TV set (40–50 inch) with energy efficiency class A fell from € 750 in 2012 to € 628 in 2013. The average price of a TV (30-40 inch) with energy efficiency class A fell from € 401 in 2012 to € 331 in 2013 in EU-24.

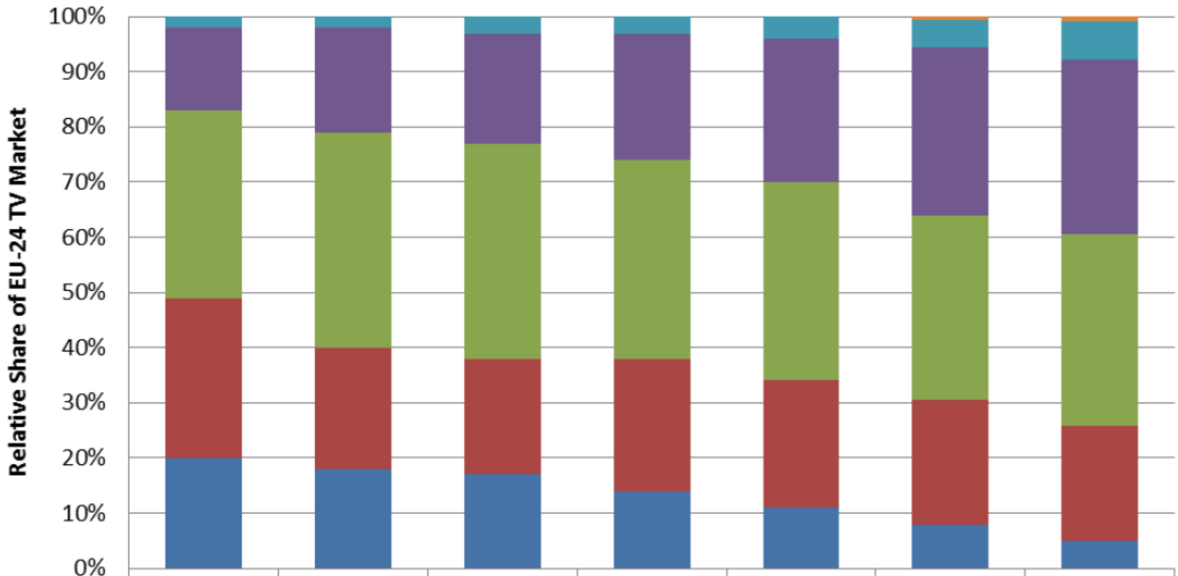
A survey carried out by the market research institute NPD DisplaySearch[64] showed that the demand for larger screens and better picture quality, together with falling prices, are the main reasons why people exchange their TV set. A defect was another important reason, but it was rarely the decisive factor. New functions, such as LED-background illumination, 3-D and Internet connectivity were only found to play a subordinate role as stimuli for buying a new TV set.

According to CLASP (2014), the market share of televisions with larger screen diagonals has continually increased in EU-24, as the following figure shows:

[64] Sources:
http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/110608_new_tv_features_not_strong_drivers_of_new_tv_purchases.asp; Accessed 02.02.2015

http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/110421_displaysearch_study_reveals_consumers_are_replacing_tvs_faster_than_ever.asp; Accessed 02.02.2015

Figure 66 Increasing sales of larger televisions in EU-24



	2007	2008	2009	2010	2011	2012	2013
>60"						0.7%	0.9%
50"-60"	2%	2%	3%	3%	4%	5%	7%
40"-50"	15%	19%	20%	23%	26%	31%	32%
30"-40"	34%	39%	39%	36%	36%	34%	35%
20"-30"	29%	22%	21%	24%	23%	23%	21%
<20"	20%	18%	17%	14%	11%	8%	5%

Source: CLASP (2014), calculated from GfK data

Figure 66 shows a doubling of the market share of televisions with screen diagonals of 40-50 inches between 2007 and 2013 from 15% to 32% in EU24. The market share of televisions with screen diagonals of 20–30 inches fell from 29% to 21% in the period from 2007 to 2013, while the market share of 30–40-inch televisions remained relatively stable over the same period (ca. 35%).

A further survey by DisplaySearch in Great Britain came to similar conclusions. There consumers who had bought a TV set within the previous 12 months or intended to do so in the coming 12 months were asked about their motivation[65]. The following considerations played a main role in the purchase of a TV set:

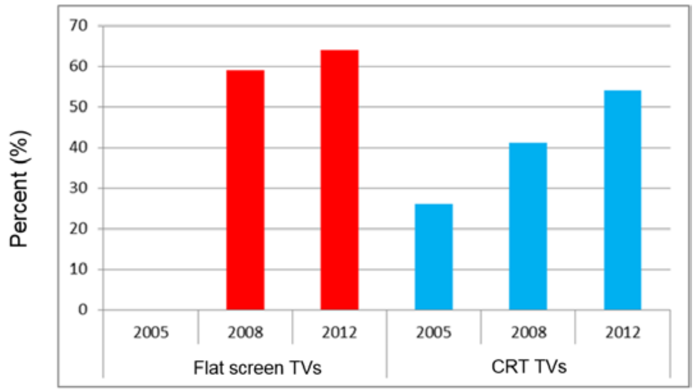
- Picture quality
- Price
- Screen size
- Sound quality
- Type of screen
- Full HD / 1080

[65] Source: http://www.dvd-and-beyond.com/display-article.php?article=1856, Accessed 02.02.2015

- Design

In Section **Fehler! Verweisquelle konnte nicht gefunden werden.** it was shown that in 2012 more than 60% of working flat-screen TV sets were replaced because the consumers wanted to have a better set (Figure 67).

Figure 67 Annual proportion of TV sets that were still functional but were replaced by a better TV set



Source: Our presentation, calculated from GfK data

The analysis of the causes of obsolescence in televisions shows that psychological obsolescence is much more important than material or functional obsolescence.

6.2.4 Economic obsolescence

Fehler! Verweisquelle konnte nicht gefunden werden. shows the repair costs for faults due to defective components (costs for parts and labour). This does not include call-out fees, which may be € 40 to € 80, depending on the circumstances.

Table 28 Repair costs according to repair companies

Component	Labour costs	Cost of part	Duration of repair
Housing	€ 50 / € 25 (+VAT)	€ 140 / € 25–75	60 min. / 30 min.
Switch	€ 50 / € 25-37.50 (+VAT)	€20 / € 12-15	30 min. / 30-45 min.
Interfaces / ports	€ 50 / -	-	60 min. / -
Stand	€ 13 / -	€ 80 / -	
Display or Monitor unit	€ 75 / € 50–100 (+VAT)	€ 450 / € 300-400 (control circuit board: € 80-180)	90 min. / 60–120 min. (or longer with error search)
Plug connectors	€ 25 / -		25 min. / -
Aluminium-electrolytic capacitors	€ 30 / € 25–100 (+VAT)	€ 1 / € 1-2	40 min. / 30–120 min. (or longer with error search)
Solder connections	€ 30 / -		40 min. / -
Power supply card	€ 50 / € 25-50 (+VAT)	€ 110 / € 50–200	60 min. / 30-60 min. (or longer with error search)
Mainboard	€ 40 / € 25-50 (+VAT)	€ 210 / € 120–200	45 min. / 30–60 min. (or longer with error search)
Loudspeakers	€ 25 / -	€ 50 / -	20 min. / -
Screws	€ 13 / -	€ 2 / -	3 min. / -

Components that fail relatively frequently such as the display or monitor unit and power supply card (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**) can lead to repair costs of several hundred euros. In relation falling prices of new TVs (see Section 6.2.3) this can possibly result in consumers no longer having a TV set repaired and instead buying a new one.

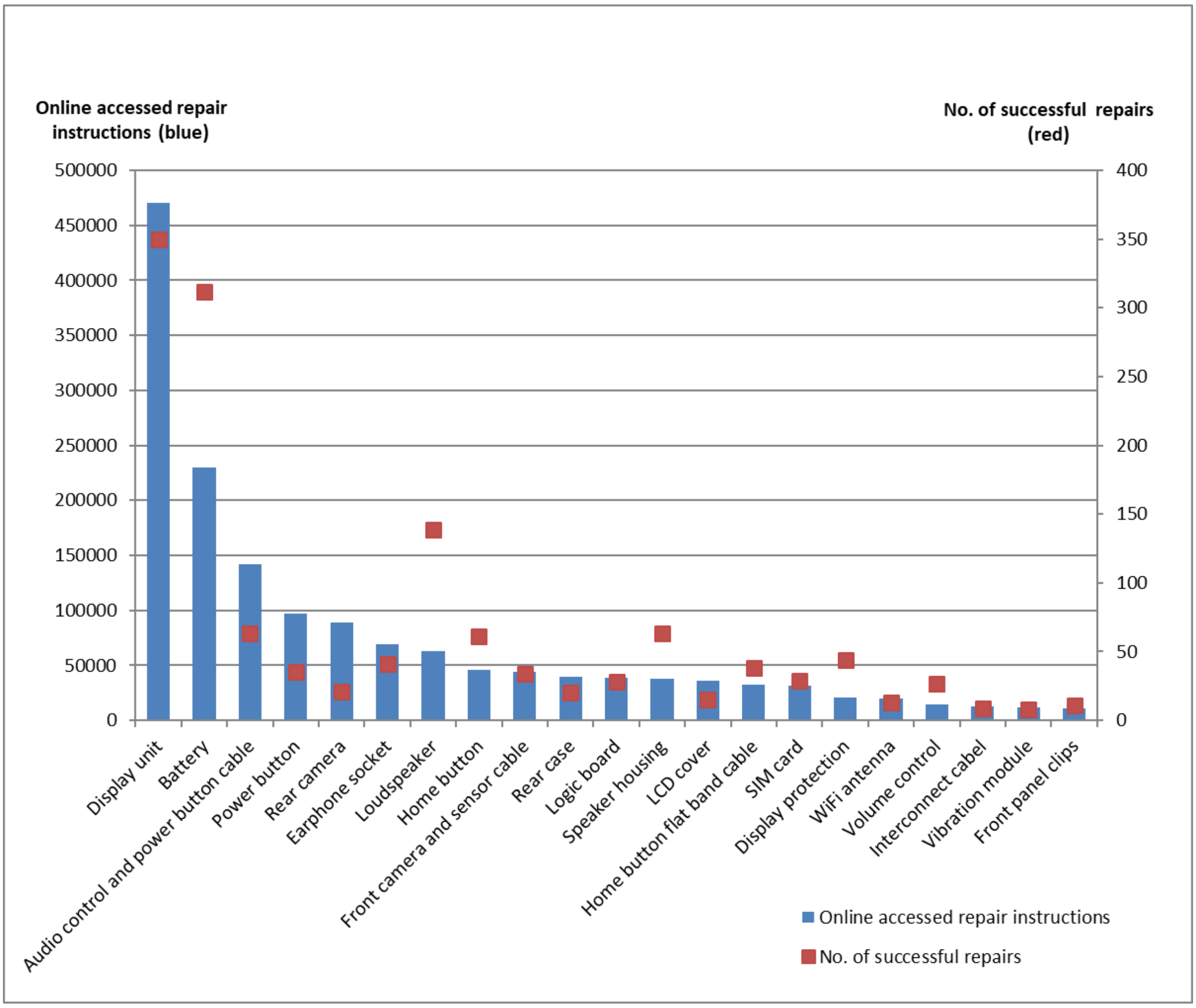
6.3 Causal analysis – Smartphones/mobile phones

For smartphones/mobile phones, the online repair platform www.ifixit.com was evaluated. The number of times repair instructions were accessed can be used to draw conclusions about the reasons why the devices had to be repaired.

As shown in Figure 68, for iPhones of the 5th generation the most common cause (in blue) is a faulty display assembly, followed by the battery, and then the audio control and power button cable. In fourth place is the power button.

Figure 68 also shows the numbers of successful repairs (red, right axis). For many components, the number of repairs corresponds to the number of downloaded repair instructions. However, for the battery, earpiece speaker and speaker enclosure there were relatively more successful replacements or repairs (Figure 68).

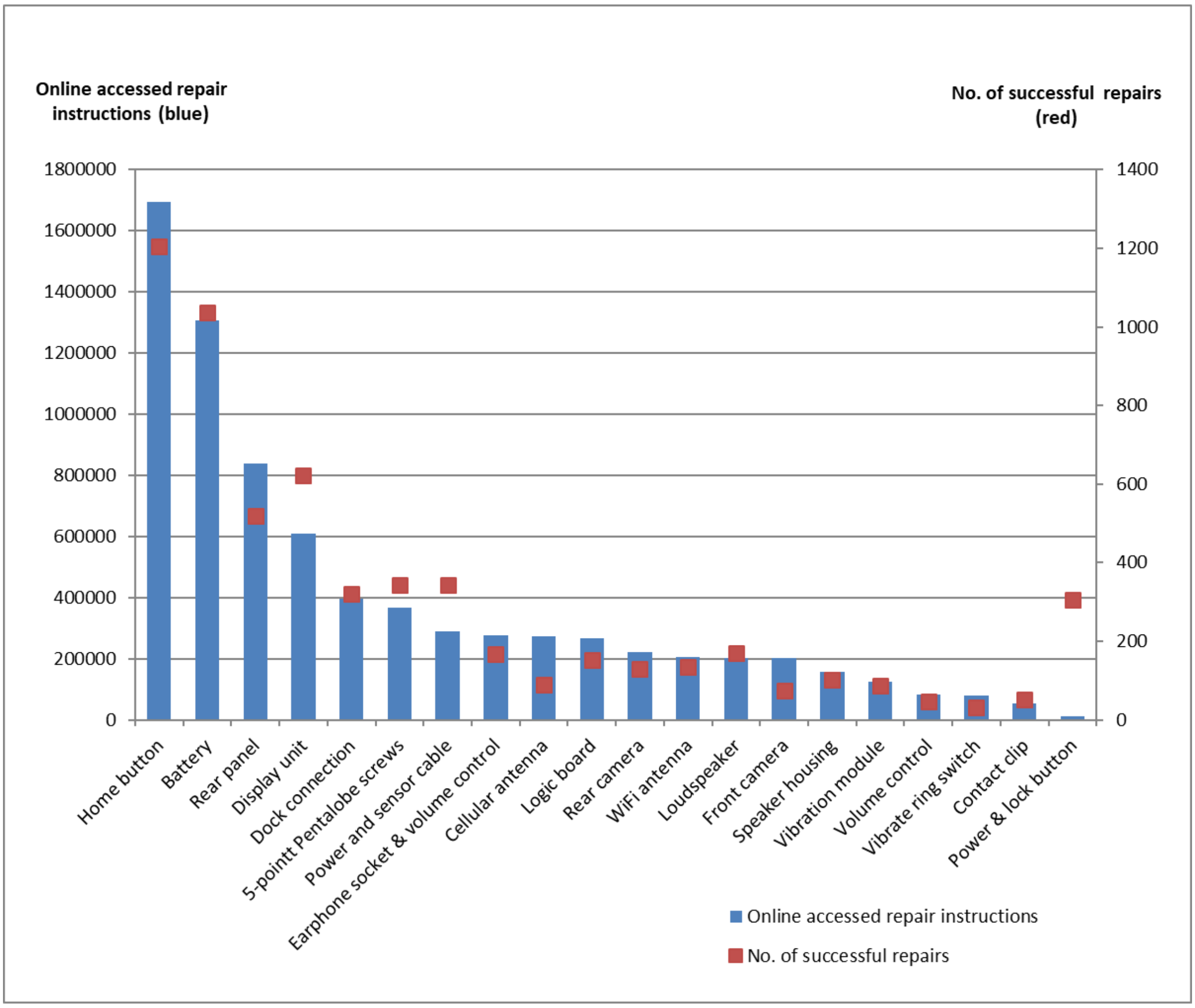
Figure 68 Defects and repairs of components of the iPhone 5



Source: Evaluation on the basis of www.ifixit.com (evaluated on 14.02.2014)

As a comparison, the same evaluation was carried out for the iPhone 4. The results are presented in Figure 69.

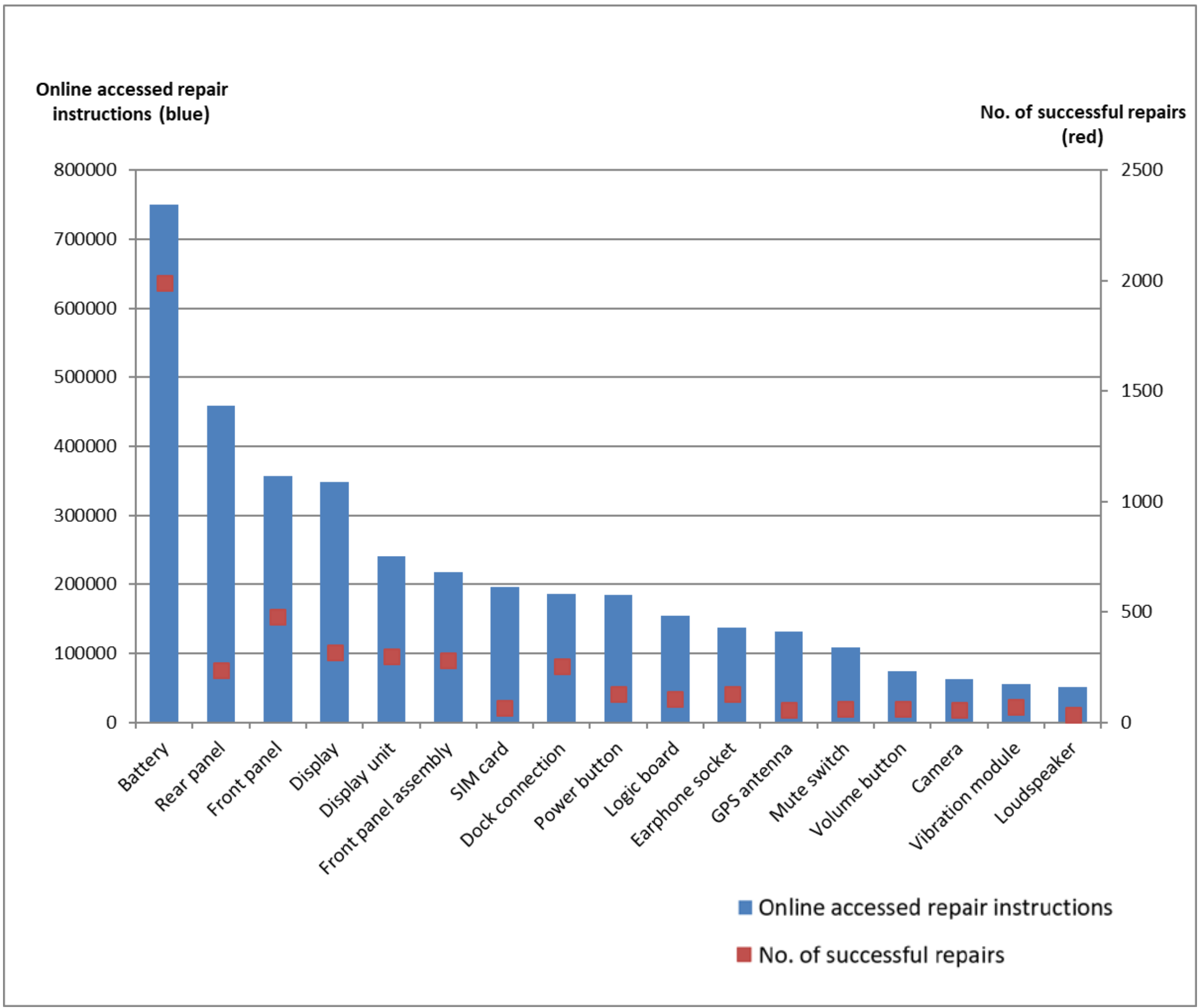
Figure 69 Defects and repairs of components of the iPhone 4



Source: Evaluation on the basis of www.ifixit.com (evaluated on 14.02.2014)

The evaluation for the iPhone 3 GS is shown in Figure 70.

Figure 70 Defects and repairs of components of the iPhone 3GS

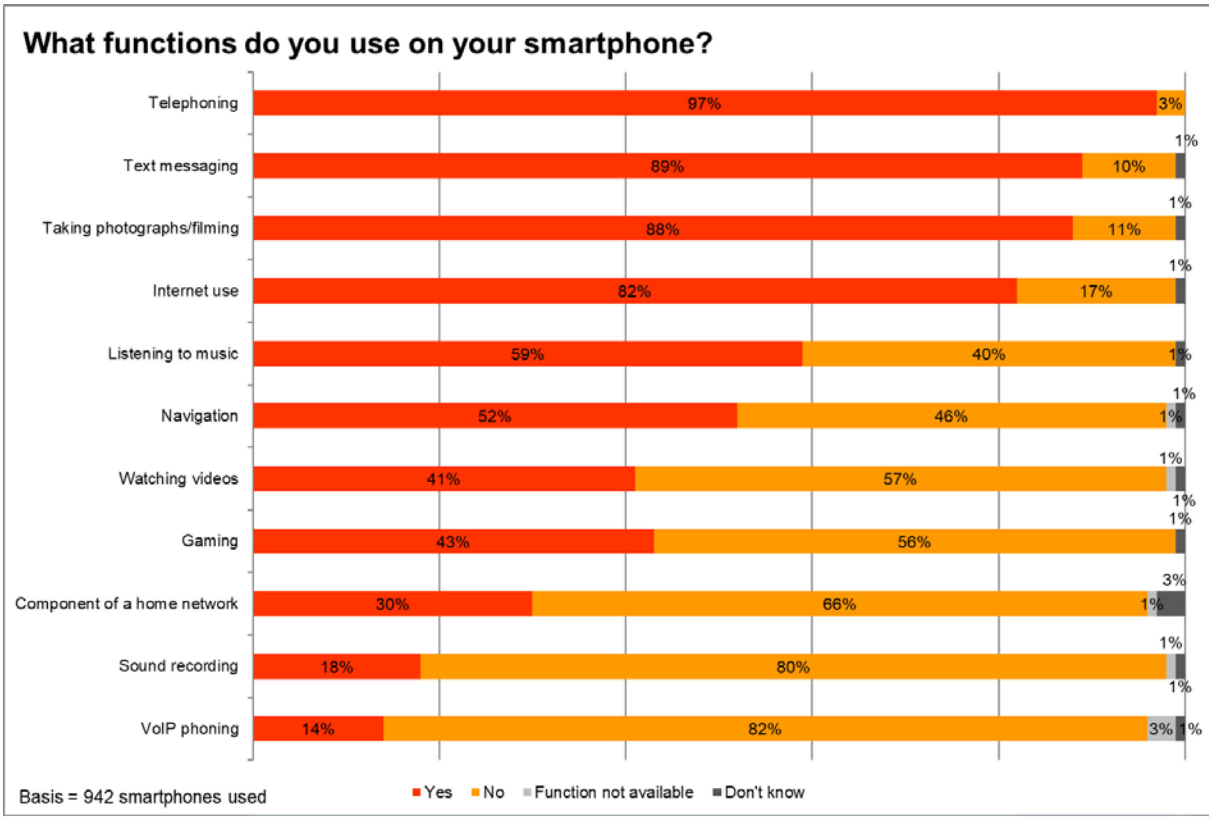


Source: Evaluation on the basis of www.ifixit.com (evaluated on 14.02.2014)

The evaluation of the three iPhone models shows that batteries are by far the most frequent reason for a repair or replacement. This is supported by the large number of accessed repair instructions for iPhone 5, iPhone 4 and iPhone 3 from www.ifixit.com. Along with batteries, the display unit, power button, and home button are important reasons for repairs to iPhone models.

The frequent need for a repair or the exchange of the battery in smartphones is possibly due to the increasing intensity of use and the increasing variety of functions offered by these devices. In contrast to standard mobile phones, smartphones offer consumers a wider variety of functions for their use (Figure 71):

Figure 71 Use of functions of a smartphone



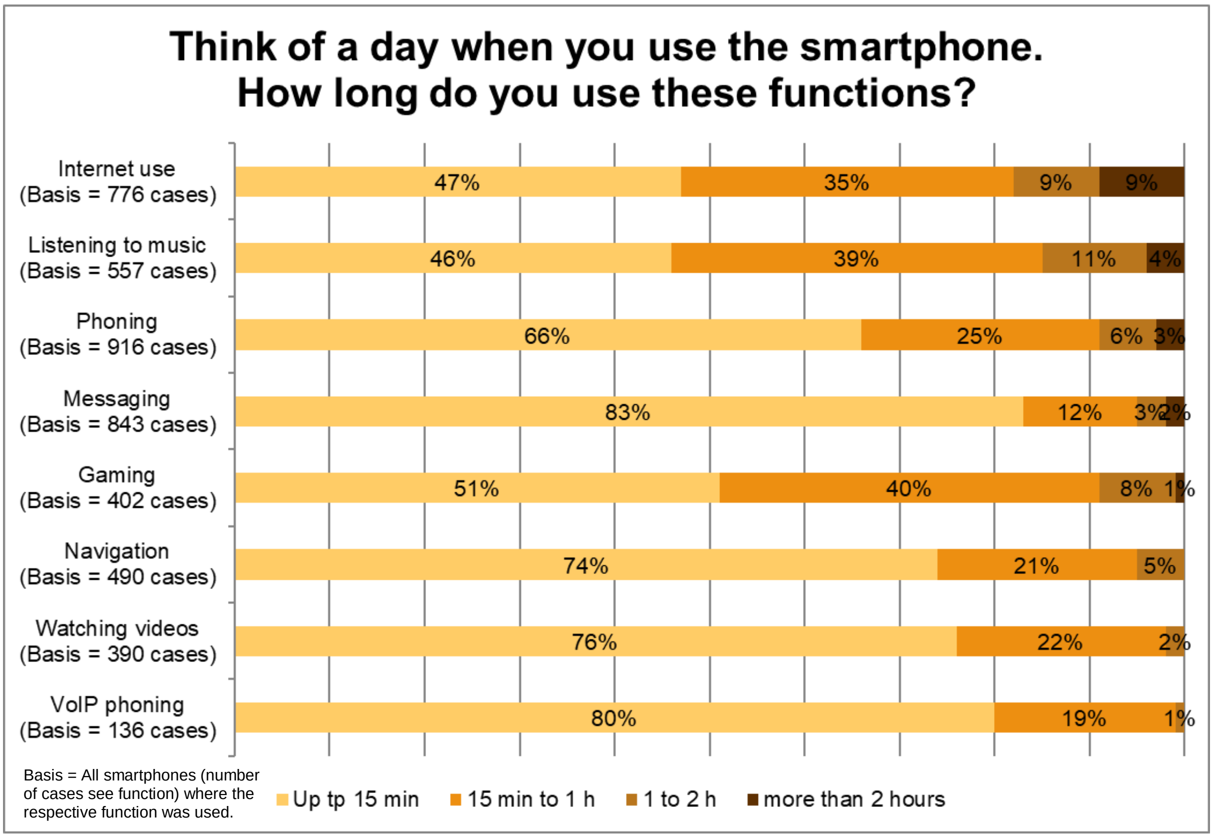
Source: Prakash et al. (2014b)

As Figure 71 shows, more than 80% of smartphones are used for Internet access, more than 50% for navigation, more than 40% for videos, and nearly 90% for taking photographs. According to an Online Study[66] by Germany's public television stations (2014), the spread of smartphones and tablets resulted in a doubling of mobile online use within two years: The proportion of those with Web access who were using the Internet while on the move was 23% in 2012, increased to 41% in 2013, and was 50% a year later. People with smartphone or tablets were online more often (6.3 days weekly) and longer (195 minutes) than people who did not use a mobile device (5.1 days weekly; 108 minutes) (ARD/ZDF, 2014).

Figure 72 shows how intensively the various functions of a smartphone are used on average every day.

[66] Source: www.ard-zdf-onlinestudie.de/; Accessed 02.02.2015

Figure 72 Daily use of smartphones



Source: Prakash et al. (2014b)

The frequent repairs required for smartphone components could be related to the increasingly intensive use of smartphones.

In order to test whether the potential to exchange batteries is important for the longer use of a smartphone, battery disassembly analyses on the iFixit platform were analysed separately (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 29 Battery disassembly analysis for smartphones by iFixit (Source: iFixit, 2015a)

Model	Integrated battery? (Yes/No)	What steps did the disassembly involve?	How many steps were involved?	What tools were used?	How long (in minutes) did it take?	Instructions available? (Yes/No)
Samsung Galaxy S4	No	1. Loosen back cover 2. Remove battery	2	None	0.5	Yes
iPhone 6	Yes	1. Undo 2 screws 2. Separate display from phone with suction cups 3. Undo 5 screws 4. Remove cover of the cables of the display unit 5. Disconnect camera and sensor, home button cable, digitizer cable and display data cable 6. Lift front cover from rear case 7. Undo 2 screws of the battery connection Remove cover of the battery connection 8. Undo battery connection 9. 2 Loosen battery adhesive 10. Remove battery	11	P2 Pentalobe screwdriver Small suction cups Soft plastic opening tool (spudger) Tweezers Hot-air gun and plastic card Phillips #00 screwdriver	15	Yes
Fairphone	No	1. Loosen back cover 2. Remove battery	2	None	0.5	Yes
Samsung Galaxy S5	No	1. Loosen back cover 2. Remove battery	2	None	0.5	Yes
Motorola Atrix 4G	No	1. Loosen back cover 2. Remove battery	2	None	0.5	Yes
HTC One	Yes	1. Heat the bonded areas, lift the display 2. Remove the back casing with the spatula to reveal the internal components 3. Unscrew the battery plug from the motherboard 4. Remove motherboard 5. Lever out the battery	5	Hot-air gun Metal spatula Phillips #00 screwdriver Soft plastic opening tool Small suction cups Antistatic spatula Tweezers	20	Yes

Fehler! Verweisquelle konnte nicht gefunden werden. shows that the removal of batteries that were not integrated in the device was possible in less than a minute. In contrast, for two models it took 15–20 minutes using a number of special tools to remove the battery.

iFixit has carried out similar analyses for the disassembly of smartphone displays. Table 30 shows that the display disassemble took between 5 and 35 minutes.

Table 30 Display disassembly for smartphones (Source: iFixit, 2015b)

Model	What steps did the disassembly involve?	How many steps were involved?	What tools were used?	How long (in minutes) did it take?	Instructions available (Yes/No)
Samsung Galaxy S4	1. Loosen back cover 2. Remove microSD cards 3. Remove battery 4. Remove SIM-card 5. Undo 9 screws 6. Release clips 7. Remove display unit from frame 8. Disconnect USB port, camera cable, loudspeaker cable, headset socket cable, digitizer cable and antenna cable from mainboard 9. Undo another screw and remove motherboard 10. Undo the last of the 11 screws and separate earphone socket from display 11. Loosen the clips of the display unit 12. Disconnect camera from display 13. Disconnect loudspeakers from display 14. Disconnect vibration unit from display 15. Disconnect USB-port from display 16. Undo antenna cable	16	Phillips #00 screwdriver Antistatic spatula Soft plastic opening tool Tweezers	10	Yes

Model	What steps did the disassembly involve?	How many steps were involved?	What tools were used?	How long (in minutes) did it take?	Instructions available (Yes/No)
iPhone 6	1. Undo 2 screws 2. Separate display from sub-unit using suction cups 3. Undo 5 screws 4. Remove cover of the display unit cables 5. Disconnect camera and sensor, home button cable, digitaliser cable, display data cable 6. Raise front cover from sub-unit	6	P2 Pentalobe screwdriver Small suction cups Soft plastic opening tool Tweezers Phillips #00 screwdriver	10	Yes
Fairphone	1. Open battery cover 2. Remove battery 3. Remove SIM-card 4. Undo 5 3.9 mm Phillips #000 screws 5. Separate casing from with plectra and remove 6. Disconnect loudspeaker button and power switch 7. Disconnect antenna cable plug with spatula. 8. Expose connection of digitaliser cable by pulling up foam band 9. Disconnect digitaliser cable 10. Undo 3x 2.5mm Phillips #000 screws 11. Slightly raise motherboard 12. Disconnect data cable from rear side of motherboard 13. Remove motherboard 14. Disconnect Wi-Fi-antenna cable, 15. Disconnect daughter board-cable 16. Undo 2x 2.5mm Phillips #000 screws and 2x 1.6mm Phillips #000 screws	18	6 plastic plectrums to open appliance Phillips #000 screwdriver Antistatic spatula Tweezers	5	Yes

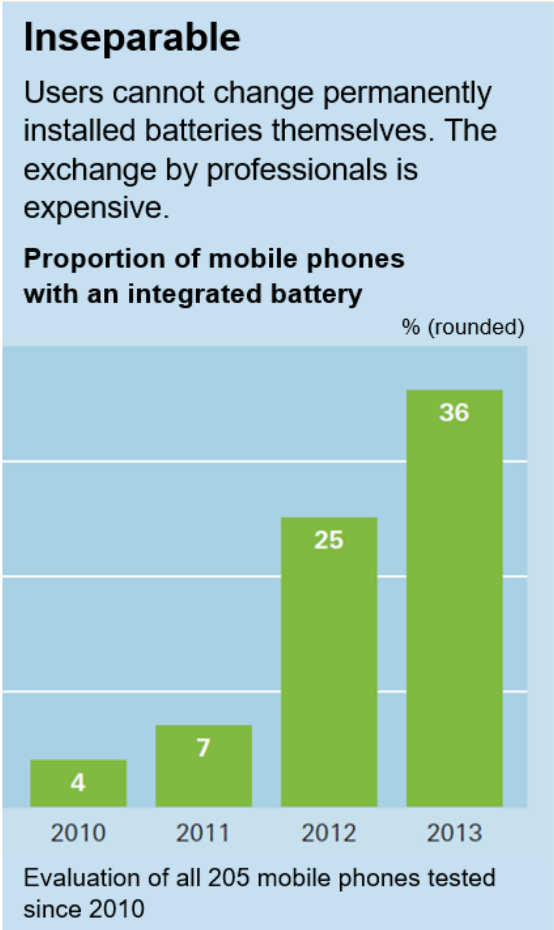
Model	What steps did the disassembly involve?	How many steps were involved?	What tools were used?	How long (in minutes) did it take?	Instructions available (Yes/No)
	17. Slightly raise bonded connection of the motherboard 18. Disconnect earphone from the display unit, disconnect antenna cable, remove rubber conduit at the recess next to the opening for the front camera.				
Samsung Galaxy S5	1. Loosen back cover 2. Remove battery 3. Take out microSD card 4. Take out SIM card 5. Loosen cover of the home button cable 6. Disconnect home button cable 7. Heat edges of glass cover to weaken adhesive bonds. Disconnect the cover using the plectra. 8. Disconnect the cable of the soft buttons 9. Disconnect display cable and raise display	9	Soft plastic opening tool Phillips #00 screwdriver 6 plastic plectra Hot-air gun Antistatic spatula	20	Yes
Motorola Atrix 4G	1. Remove rear cover 2. Lever out battery with spatula at the points marked 3. Undo 8 T5 screws and remove the back part with a spatula 4. Unplug antenna from motherboard 5. Loosen motherboard with spatula and fold up 6. Disconnect cable connection from motherboard 7. Heat adhesive bond of glass cover.	9	Hot-air gun Soft plastic opening tool Antistatic spatula T5 Torx screwdriver	5	Yes

Model	What steps did the disassembly involve?	How many steps were involved?	What tools were used?	How long (in minutes) did it take?	Instructions available (Yes/No)
	8. Lever out glass cover 9. Disconnect digitaliser cable				
HTC One	1. Heat the bonded areas with hot-air gun, lift the display with suction cup 2. Expose the interior components by freeing the rear housing with the spatula 3. Unscrew battery connection from motherboard 4. Remove motherboard 5. Lever out the battery 6. Lever out the display	6	Hot-air gun Metal spatula Phillips #00 screwdriver Soft plastic opening tool Small suction cups Antistatic spatula Tweezers	35	Yes

Table 30 shows that display assembly took between 5 and 35 minutes for the smartphone models examined.

Figure 73 shows the continual increase in the proportion of mobile phones with integrated batteries between 2010 and 2013. In 2013, nearly 36% of the mobile phones tested by Stiftung Warentest had an integrated battery:

Figure 73 Mobile phones with an integrated battery tested by Stiftung Warentest



Based on: test 9/2013, Stiftung Warentest (2013)

In its magazine, test 11/2014, Stiftung Warentest tested 20 smartphones. Seven of the models contained a battery that could not be replaced by the user. Four of these models were rated as "satisfactory" regarding battery quality (Stiftung Warentest 2014a)[67]. In an earlier test (7/2014), Stiftung Warentest found that eleven out of 20 smartphone models they tested had batteries that could not be replaced by the user. Of these three models were rated "satisfactory" and one model only "adequate" (Stiftung Warentest 2014b).

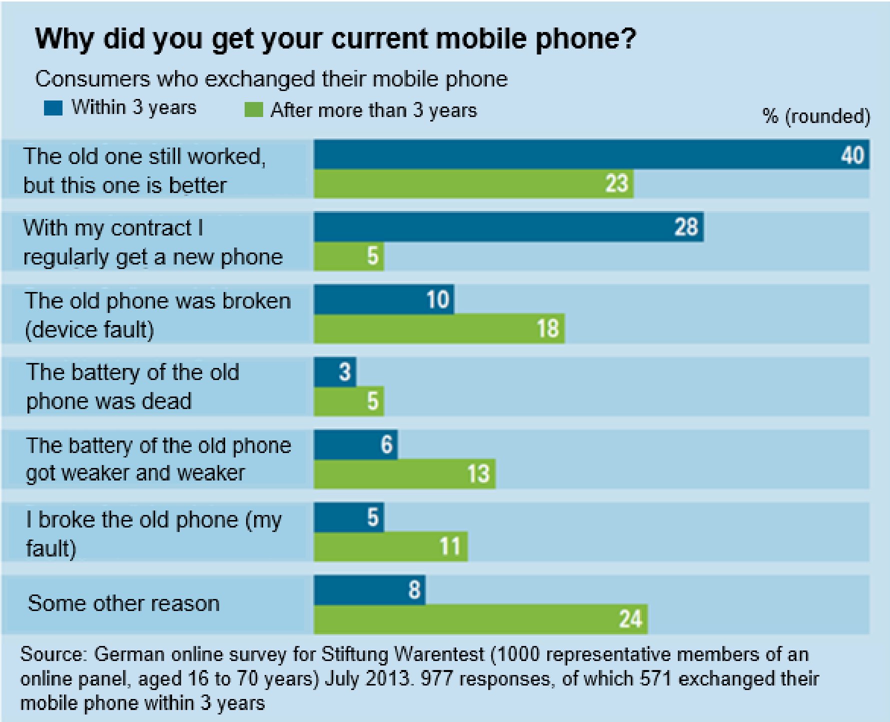
The fact that in some models the battery cannot be exchanged by the user and are also given poorer quality assessments for the battery performance suggests that these models may possibly be replaced in the course of their use due to poor battery performance.

However, another survey test by Stiftung Warentest shows that only 9% of respondents who exchanged their mobile phone within three year did so because of a faulty or weak battery. 68%

[67] Test method of Stiftung Warentest for batteries: The operating periods were determined when phoning in the GSM/UMTS network and when on standby, for Internet surfing and the online GPS-use in the UMTS/LTE network. The recharging time was also determined and the possibility of replacement of the battery by the user was evaluated (Stiftung Warentest 2014b).

said that either they simply wanted a better phone (40%) or that they regularly got a new phone because of their contract (28%).

Figure 74 Survey by Stiftung Warentest of reasons for replacing a mobile phone



Based on: test 9/2013, Stiftung Warentest (2013)

In Section 5.4.2, the results of a survey by Stiftung Warentest were presented according to which 42% of users in Germany exchanged their mobile phone within two years. Some 16% of users exchanged their mobile phone every three years (Figure 54). The results of a study by the Information Centre for Mobile Telecommunications (IZMF 2013) were similar. According to this study, 48% of mobile phone users plan to use their mobile phone /smartphone for a maximum of two years.

In summary, psychological obsolescence, i.e. the wish to have a better device, plays a key role in limiting the period of use of smartphones.

6.4 Causal analysis – Laptops

6.4.1 Material obsolescence

Since lap-top computers are designed for mobile use, the demands placed on them differ from the applying for computers intended for stationary use. The weight and the size are more relevant for mobile use, and also the capacity of the battery (time off grid). A robust casing is also very important to protect the components during mobile use. A Forsa survey shows that a declining battery power or shorter battery operating times limit the lifespan, in particular if the battery cannot easily be exchanged either by the user or by a repair shop round the corner, (Forsa 2013).

With increasing miniaturisation, additional constraints are placed on the components and the design regarding the lack of space, the heat development within the housing, and the weight of the appliance. Technological progress and new functions lead to the growing complexity of the electronic circuitry, increasing power consumption (e.g. for watching videos) and new component technologies and materials (WRAP 2011b)[51].

6.4.1.1 Expert interviews

In expert interviews, six repair companies supplied data about possible material causes of obsolescence of laptops (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**), with the responses of one repair company referring solely to business laptops. The following information and data are therefore not representative. But the repairers draw on many years of practical experience. The individual parts of laptops and the responses of repair companies in expert interviews about the likelihood of failure are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

The responses provide a first approximation of the specific hotspots and key factors limiting the lifespan of the overall system.

Table 31 Likelihood of failure of components of laptops

Component	Likelihood of failure			
	never	rarely	often	very often
Mainboard		R3, R4	R1, R2	
Processor	R1	R2		
Processor cooler/fan		R2, R4	R1, R3	
Memory		R3, R4	R1	R2
Graphics chip		R4	R1, R2	R3
Power supply		R3, R4	R1, R2	
Ethernet		R1-3, R4		
WLAN antenna (WLAN card)		R1, R2		
Hard drive			R3, R4	R1, R2
Optical drive (CD/DVD)		R1-3, R4		
Integrated controller		R1, R2		
Peripheral interface (USB-Ports, 3.5 mm sockets, VGA or DVI Ports etc.)		R2, R3, R4	R1	
Display (and contrast)		R4	R1, R2, R3	
Display cover (and hinge)		R4	R1, R2, R3	
Battery			R1, R3, R4	R2
Touchpad		R1, R2		
Laptop housing		R4	R1, R2, R3	
Keyboard		R4	R3	

Source: Our survey; Repair services R1–R3 refer to consumer laptops, R4 relates to business laptops[68]

[68] The responses of two further repair companies are not included in **Fehler! Verweisquelle konnte nicht gefunden werden.**, but they give a very similar picture of the likelihood of faults.

For consumer laptops, the components that fail most frequently are hard drives, memory, graphics chips, and batteries (all very often) followed by mainboards, processor fans, power supply units, and peripheral interfaces, displays and covers (hinges) and laptop housings (all often, see **Fehler! Verweisquelle konnte nicht gefunden werden.**). There are differences between the three repair companies regarding the likelihood of failure of individual components (e.g. mainboard, power supply, and peripheral interfaces).

There are noticeable differences between business laptops (R4) and consumer laptops. According to an experienced repair company, the hard drives and batteries of business laptops frequently fail. All other components rarely fail.

The main causes of failures according to the repair companies are:

- Thermal problems,
- Mechanical wear,
- Careless handling.

The sub-category of Ultrabooks are intended more specifically for mobile use than conventional laptops. A radically different design is used to reduce the weight without impairing performance. The main differences are the restricted possibilities for upgrading Ultrabooks, and the limited scope for their repair, disassembly and recycling.

In contrast to conventional laptops, the following factors can limit the lifespan:

- Integrated batteries,
- Soldered memory elements
- Integrated hard drives.

The experts from the repair companies also emphasise that the lifespan of the electrical and electronic parts and components is a key factor determining the functional durability of the device. This depends on the ratings of the components and their thermal exposure. As already shown for aluminium- electrolytic capacitors in Section 6.2.1.1, placing components close to sources of heat can shorten their lifespan. They are subjected to thermal stress and also the ageing processes of the materials are accelerated. Over-heating in laptops is a considerable problem for designers. Fans and coolers draw in air over the cooling vanes and past sensitive components (e.g. processor, graphics card). But they also bring in dust and airborne matter, so that the air vents gradually become blocked. The result is that the fan has to rotate more quickly and this in turn increases the power consumption and the wear of the rotor motors. With time, the internal temperature levels rise, which can result in damage to processors, graphics cards, and other components.

The expert interviewed in this study explained that different parts and components were used in the various production series of the same product. The supply markets for electrical and electronic parts and components are very dynamic, with large production volumes and low profit margins. The intense competition leads to quality fluctuations. Frequent insolvencies make it difficult to track deliveries back along the supply chain. According to manufacturers, despite individual tests and high-quality specifications for parts and components it is often not possible to ensure that suppliers meet guaranteed specifications.

6.4.1.2 Literature research about causes of errors

SquareTrade (2009) studied data from a warranty service for the first three years of use of 30,000 laptops from ten manufacturers. The study concluded that 20.4% of the devices failed due to hardware faults within the first three years, and a further 10.6% of the devices failed within the same period due to accidents and inappropriate use.

A study of 300 businesses by IDC (2012) on behalf of a manufacturer of particularly robust laptops showed that every year some 14% of the laptops investigated here had to be repaired or replaced due to a hardware defect, and 9.5% as the result of an accident. The most common accidents involved dropping the laptop, spilling liquids on the keyboard, or knocking the computer off the desk. According to the study the most frequent components to fail were the keyboard and the display, followed by less exposed components such as the battery and hard drive (IDC 2012).

In many product tests of laptops presented in computer magazines, the haptic and ergonomic properties of laptops are assessed (e.g. rounded corners, key touch response, ventilator noise). Problems identified include the lid hinges and other exposed component connections. Unintentional impacts, or continual normal use can lead to defects or the failure of the device. A robust housing helps to protect internal components against damage if the device is dropped or exposed to unintentional mechanical impacts. Broken hinges and other connections can often only be repaired provisionally (Heise 2013).

A study of laptops by the British research institute WRAP (WRAP 2011b)[51] reports that 7% of appliances failed during the first year, some 20% in the second year and by the end of the third year one third of the devices had already failed (WRAP 2011b). Critical material factors relating to the design and construction of the casing were identified as the most frequent sources of failures (WRAP 2011b):

- LCD displays of laptops break and are difficult to remove from the lid,
- Attachment of the lid and hinges for laptops,
- Rapid fatigue if the hinge is frequently used,
- Electrical connections with only plastic clips and susceptible to damage from voltage spikes when exposed to electric charges,
- In some designs, electrical parts tend to overheat (in particular hard drives and integrated components), e.g. if air vents are oriented to the underside of the computer,
- Keyboard defects, in particular when individual keys cannot be removed and replaced,
- Overheating of components due to inadequate ventilation, blocked air vents or inadequate access for maintenance.

6.4.1.3 Results of the internet-based consumer survey

All responses in this section relate to the most recent laptop disposed of by the 655 participants of the consumer survey carried out as part of the project.

New or second -hand purchased laptop

80 % of the participants said that the laptop they disposed of had been new when they bought it, and 20 % said that their laptop had been second-hand.

Table 32 Numbers of laptops that were new or second-hand when purchased

Was the laptop new or second-hand when purchased?	Frequency	%
New	522	79.7
Second-hand	131	20.0
I don't know.	2	0.3
Total	655	100.0

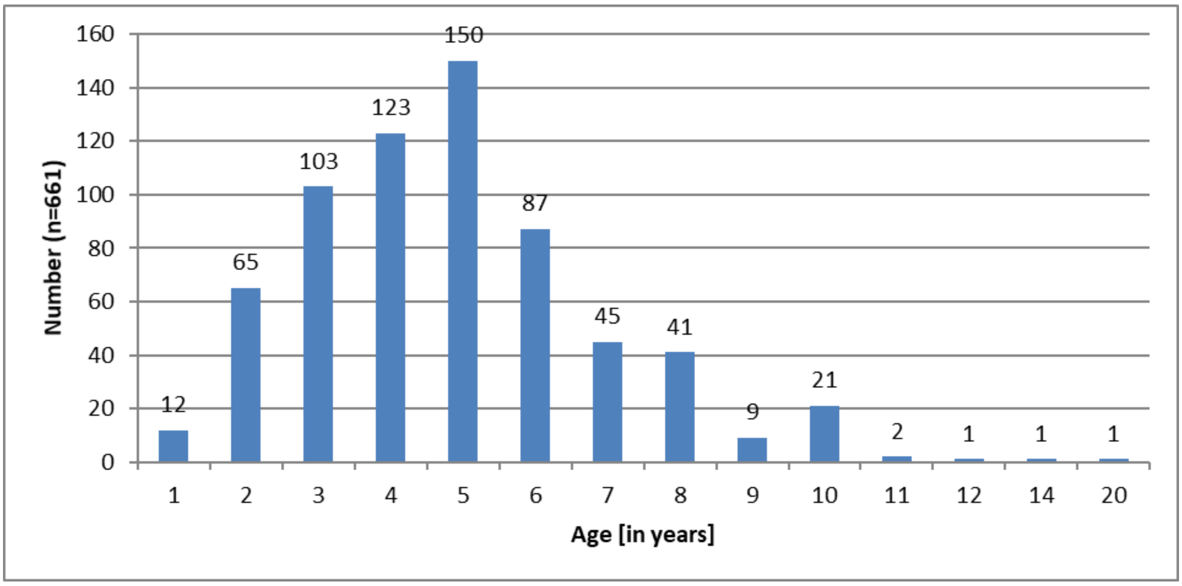
Age of the laptop

On average, when they were disposed of the laptops were 4.9 years old (standard deviation 2.1 years). The youngest laptop was only one year old, the oldest 20 years. Less than 20 % of the laptops were still in use after 6 years, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. Figure 75 shows the age distribution.

Table 33 Age-distribution of the laptops

How old was your laptop in the end? If you do not know, please estimate a value [in years].								
N	Mean	SD.	Min.	Max	25th percentile	Median	75th percentile	Range
661	4.9	2.1	1	20	3	5	6	19

Figure 75 Age of the laptops



Source: Our presentation

Price of the laptop

Just over half of the laptops were medium-priced appliances and 32 % were expensive appliances, see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 34 Price of the laptop

How expensive was this laptop?	Frequency	%
An inexpensive appliance (no name)	67	10.1
A medium-priced appliance	349	52.8
An expensive appliance (Top-brand product)	210	31.8
I don’t know.	35	5.3
Total	661	100.0

Repair of the laptop

30 % of the laptops had been repaired at some stage. 37 % of these repairs were carried out under warranty; 55 % of the repairs were carried out after the warranty had expired. 68 % of the old laptops had never been repaired. See **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 35 Repair of the laptop

Was this laptop ever repaired?	Frequency	%
Yes	196	30.0
No	442	67.6
I don’t know.	17	2.4
Total	655	100.0

Table 36 Repair under warranty – laptop

Was the repair carried out during the warranty period?	Frequency	%
The repair was carried out in the warranty period.	71	37.4
The repair was carried out after the warranty had expired.	104	54.7
I don’t know whether the repair was carried out during the warranty period.	15	7.9
Total	190	100.0

Frequency of use of the laptop

51 % of the participants used the laptop several times a day, and 31 % daily. 14 % used the laptop several times a week. Relatively few used their laptop less frequently (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 37 Frequency of use of the laptop

How frequently have you used this laptop as a rule If you do not know exactly, please estimate a value	Frequency	%
Almost never	5	0.8
Once a month	7	1.1
Once a week	15	2.3

How frequently have you used this laptop as a rule If you do not know exactly, please estimate a value	Frequency	%
Several times a week	94	14.3
Daily	202	30.7
Several times a day	336	51.0
Total	659	100.0

Fate of the laptop

In 41 % of cases, the participants said that they had kept the old laptop. Only 23 % of the laptops were sent for disposal, while 33 % were sold or given away (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). It is suspected that the laptops were kept because of the confidential data stored on them.

Table 38 Fate of the laptop

What did you do with the laptop?	Frequency	%
Disposal	154	23.3
Passed it on (sold, given away)	215	32.5
Kept it	270	40.8
Something else	22	3.3
Total	661	100.0

Reason for purchase of a new laptop

In 46% of the cases, the old laptop was disposed of because it was defective. 25% of the laptops were replaced because they did not have enough functions. 17% of the participants had some other reason for disposing with.

Table 39 The reason for disposing of a laptop

Why did you dispose of the laptop? Choose the most appropriate reason	Frequency	%
The laptop was defective	305	46.1
I didn’t like the laptop anymore	38	5.7
The laptop didn’t have enough functions	162	24.5
I had been given a new laptop	37	5.6
I had some other reason	115	17.4
The laptop was not energy-efficient enough.	4	0.6
Total	661	100.0

Satisfaction with the lifespan of the laptop

In all, 62% of participants were satisfied with the lifespan of their laptop, and 36% were dissatisfied (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 40 Satisfaction with the lifespan of the laptop

How satisfied were you with the lifespan of the dieses laptops?	Frequency	%
The lifespan met my expectations	162	24.5
I was surprised how long the laptop lasted	64	9.7
It was time to replace the laptop with a new one	185	28.0
I expected to be able to use it longer	151	22.9
The laptop only worked for much too short a time	83	12.6
I don’t know	15	2.3
Total	660	100.0

Defect of the laptop

In about a third of cases, the battery failed, followed by hardware and mainboard (each ca. 23%), display and fan (each ca. 19%) and the graphics card (13%).

The 305 participants who reported problems with their laptop named a total of 530 defects, so that in more than half the cases there was more than one defect. This implies that one defect at first only impaired the use of the laptop and then a further defect further impaired the usability.

Table 41 Defect of the laptop

What exactly was wrong with the laptop?	Frequency	%
Battery	101	33.1
Graphics card	41	13.4
Fan	58	19.0
Power supply	35	11.5
Mainboard	70	23.0
Display	60	19.7
Keyboard	19	6.2
Hardware	72	23.6
Something else	46	15.1
I don’t know	28	9.2
Total no. of responses	530	173.8
Total no. of participants	305	100.0

6.4.2 Functional obsolescence

Functional obsolescence leads to the early exchange of products in the ICT-sector that are in fact still functional. Changes in performance requirements with the introduction of new programs and applications steadily increase the demands on memory and hard drive capacity, as well as on graphics and processor performance (Heise 2014).

Hardware drivers and functional obsolescence

The hardware components of Desktop-PCs, laptops and printers have fixed software interfaces. In the interplay of hardware and software, drivers are required for the peripheral devices. Manufacturers determine, through the availability of their driver versions, the extent to which the hardware can be used under a given operating system. If drivers are not provided for older peripherals when new operating systems are released, then these can no longer be used in full, if at all, and an exchange of the peripheral hardware seems unavoidable.

According to one of the experts consulted, this is a matter in particular for the manufacturers of peripheral products, because notification of the support and development cycles of the operating systems and the changes to the driver architecture had been given long in advance.

Operating systems and functional obsolescence

The installation of a new Windows operating systems (Windows 7 or above) was not possible for older Desktop PCs and laptops.[69] If the minimum requirements of the operating system cannot be met by the hardware it had to be replaced, even though it had not reached the end of its technical lifespan.

In April 2014, Microsoft ceased to provide support for its Windows XP operating system. This meant security-relevant updates would no longer be available that offered protection against trojans and viruses that exploit the (many) security gaps in the XP software. It also meant that the support service would not be making any new functions available.

Even after the end of support, it was estimated that more than 15% of medium-sized and large companies worldwide still had Windows XP installed on 10% of the Desktop PCs and laptops in use (Gartner 2013). On the other hand, a large number of older Desktop PCs and laptops were replaced even though they were still in working order.[70]

An expert emphasises that Windows XP is a special case, because the introduction of this operating system in many companies and households was linked to the switch to digital data processing and multimedia use. The popularity of Windows XP meant that many users had become so used to it that they were unwilling to countenance change. This effect is not found to this extent with other operating systems.

The example of Windows XP shows that a planned limitation of the software lifespan was not responsible for the subsequent mass exchange of an older hardware generation (after all, the operating system had been supported for 13 years); rather it was the technical developments that resulted in changes in the user demands on hardware and software that are no longer supported by older hardware generations.

6.4.3 Psychological obsolescence

The ICT sector is very dynamic, with short innovation cycles. An exception is the market for Desktop PCs, which is saturated and is expected to shrink rather than grow. The sales of laptops in Germany increased from less than 2 million in 2003 to more than 7 million in 2011. After this,

[69] Minimum requirements for Windows 7 were: 1GHz processor, 1 GB RAM, 16 GB hard drive capacity, DirectX 9-compatible graphics.

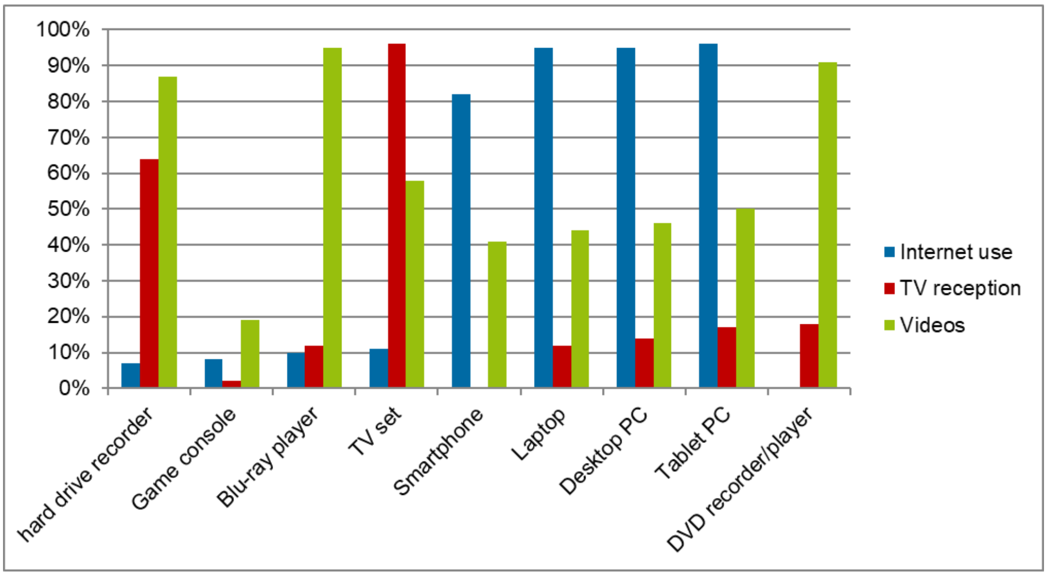
[70] Cf. http://www.zdnet.de/88195725/support-ende-von-windows-xp-intel-hebt-umsatzprognose-fuer-das-zweite-quartal/?PageSpeed=noscript

sales fell again to below 6 million in 2013, possibly due to the increased important of substitutes such as Tablet PCs (see Figure 44).

In the case of laptops, product innovations are a key factor in the segmentation of the markets, from inexpensive starter offers, through multimedia and video-processing products, to high-end gaming laptops. Whereas in the 1990s and early 2000s the main sales argument for a new laptop was the improved performance, the diversification of the performance spectrum can be expected to increase in the future.

The trend is towards a blurring of the boundaries between information, communications and consumer electronics, with products becoming increasingly multifunctional. In a study carried out for the German Federal Environmental Agency, Prakash et al. (2014b) showed that nearly 12% of laptops, 14% of Desktop PCs and 17% of tablet PCs were used for television reception, and already 44% of laptops, 46% of Desktop PCs, 41% of smartphones and 50% of Tablet PCs were used for watching videos.

Figure 76 Use of device for watching TV, videos and for Internet surfing



Source: Prakash et al. (2014b)

An evaluation of the reasons given for buying a replacement in Section **Fehler! Verweisquelle konnte nicht gefunden werden.** showed that the motivation of wanting a better product although the old one still worked played a much greater role between 2004 and 2007 than between 2010 and 2012. In Section **Fehler! Verweisquelle konnte nicht gefunden werden.** it was shown that between 2004 and 2012 the average length of use of functioning laptops, replaced because of the wish to have a better one, was some six years. This suggests that psychological obsolescence meanwhile plays a less important role for laptops. It can be concluded that the symbolic importance of laptops as a fashion item or a status symbol has declined. At the same time, it can also be assumed that the innovation cycles have slowed down and that development resources have been shifted to other sectors (e.g. tablet computers).

6.4.4 Economic obsolescence

Parts and components such as memory, hard drive, and batteries limit the lifespan if they cannot be exchanged or upgraded by the users themselves with the aid of basic tools (see JRC 2014b). In this context, important impediments are integrated batteries and special screws for memories or hard drives in Ultrabooks that require the use of non-standard tools.

In the past, German legislation for battery-operated electrical and electronic appliances simply required that is should be possible to remove batteries “without problems”. This left room for interpretation, but it was usually understood to refer to disassembly during waste disposal. The general feeling was that there was no need to require non-destructive replacement by the consumer.

In the current Electrical and Electronic Equipment Act[71], Article 4 Paragraph 1 (and also the EU Battery Directive[72] in Article 11) requires that electrical and electronic appliances that can be operated fully or in part with batteries or accumulators should as far as possible be designed so that waste batteries and accumulators can readily be removed by the end user. Otherwise, the electrical and electronic appliances are to be designed so that the waste batteries and accumulators can be removed easily by independent specialists. The European Commission[73] argues that the Battery Directive should apply throughout the lifespan, and that independent repairers and other service providers should be able to remove batteries that no longer work. So far there have been no court rulings on whether such requirements are binding.

Additionally, the German Act required in Article 4 Para. 3 that under certain circumstances it need not be possible to remove the battery (e.g. for safety reasons). This is to be judged on a case-by-case basis.

A survey of some 1,000 German consumers showed how important awareness of the possibility of having batteries exchanged in their vicinity if this option is to be used to extend the working life of appliances. 61% of the respondents said that they would have the battery exchanged and continue to use the device if they could do this at a local electronics store. Only 10% would send their device in for the battery to be replaced so that they could continue to use it (Forsa 2013).

The removal of batteries for recycling is regulated in Article 8 and Annex VII of the European Union WEEE Directive[74]. This says that appliance batteries must be handled separately. The removal during the recycling process is specified in Annex A.5 of the EN 50625-1 standard (Collection, logistics & treatment requirements for WEEE. General treatment requirements). This requires that batteries that can be accessed without the use of tools must be removed before further handling. In the case of batteries that cannot be accessed without the use of tools, the requirements are less strict, so that recyclers may sort out the batteries after mechanical pre-treatment (mechanically opening the appliance).

Fehler! Verweisquelle konnte nicht gefunden werden. shows the repair costs for laptops according to the repair services surveyed. The highest costs are incurred for replacing the mainboard, processor and graphics chip. Costs are lower for upgrading or replacing memory, processor cooler, hard drive, or display.

Table 42 Repair costs for a laptop

Component	Labour costs	Cost of parts	Time taken
Mainboard	≥ € 40/hour	≥ €250	Depends on layout

[71] German Electrical and Electronic Equipment Act (ElektroG), 20 October 2015, amended by Article 3 of the Ordinance dated 20 October 2015.

[72] Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, last amended by Directive 2013/56/EU dated 20.11.2013.

[73] See Section 2.8 in: Frequently Asked Questions on Directive 2006/66/EU on batteries and accumulators and waste batteries and accumulators (Updated version, May 2014), http://ec.europa.eu/environment/waste/batteries/pdf/faq.pdf, accessed 30.12.2015.

[74] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (OJ. L 197, 24.7.2012, p. 38).

Component	Labour costs	Cost of parts	Time taken
Processor	≥ € 40/hour	≥ €100	Depends on layout
Processor cooler/-fan	≥ € 40/hour	≥ € 40	Depends on layout
Memory	≥ € 40/hour	≥ €39	Depends on layout
Graphics chip	≥ € 40/hour	see Mainboard	as a rule impossible
Power supply	≥ € 40/hour	≥ €20	5 min.
Ethernet	≥ € 40/hour	see Mainboard	as a rule impossible
WLAN antenna	≥ € 40/hour	≥ € 40	Depends on layout
Hard drive	≥ € 40/hour	≥ € 39	Depends on layout
Optical drive (CD/DVD)	≥ € 40/hour	≥ € 39	Depends on layout
Integrated controller	≥ € 40/hour	see Mainboard	as a rule impossible
Peripheral interfaces (USB-Ports, 3.5 mm socket, VGA & DVI ports, etc.)	≥ € 40/hour	≥ €20	ca. 2-3 hours
Display (and contrast)	≥ € 40/hour	≥ €60	45 min.
Display lid (and hinge)	≥ € 40/hour	≥ €70	Depends on layout
Battery	≥ € 40/hour	≥ € 40	5 min.; longer for integrated batteries
Touchpad	≥ € 40/hour	≥ € 40	Depends on layout
Laptop housing	≥ € 40/hour	Rarely available	Depends on layout

Source: Our survey

The problem of economic obsolescence is illustrated by the following personal experience. A used laptop (Intel Core2 Duo 2.0 GHz, 1 GB RAM, 80 GB HDD, 15-inch display and DVD burner) was purchased from a private source for € 131. The laptop was praised on Internet forums because the various interfaces made it particularly suitable for upgrading. The following changes were made:

- Increased memory to 2*2 GB: € 70
- The HDD hard drive was replaced by an SSD with 150 GB, with clone software: € 90
- Adapter cable for "hard drive cloning": € 25

This cost € 316 and involved more than 3 hours work. For a repair company charging € 40 an hour for labour, the total charge would be € 436. But at the same time a supermarket discounter was offering a new laptop for € 299 with the same display size, a 500 GB hard drive, 4 GB DDR3 RAM, a DVD burner, Webcam with microphone, and a card reader.

For some laptop models, in particular in the business sector, extensive instructions are available for basic repairs, upgrades and maintenance work. The product design is often more amenable for repairs and upgrading, which reduces costs. As a result, older business appliances can also be resold at higher prices. The publication by the manufacturers of circuit diagrams and maintenance instructions provides an important basis for cost-effective repairs.

The quality of published information can vary considerably. One company, known for inexpensive consumer laptops, points out under the heading 'Maintenance' in its user manual that the fan should be freed of dust from time to time – by a service technician. But no details are given of how to open the casing, or what maintenance the fan requires. Consumers are also left in doubt about what the maintenance is likely to cost. As a result, the work may not be carried out and in many cases, this results in the overheating problems described in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**. In contrast, some manufacturers of business laptops have published detailed instructions for all their models, including for more complex repairs, maintenance work and independent upgrading (WRAP 2011b).

6.5 Causal analysis – Desktop-PCs

In this section, reasons for the failure of Desktop PCs are described. It overlaps to some extent with the previous section on laptops, in particular regarding functional obsolescence (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**).

6.5.1 Material obsolescence

Expert interviews were conducted with one repair company that responded to the enquiry of the project team about Desktop PCs. The following information is therefore not representative. However, the responses are based on many years of experience with critical factors affecting the lifespan of the various types of device.

The likelihood of failure of various parts and components of Desktop PCs presented in **Fehler! Verweisquelle konnte nicht gefunden werden.** are based on the experience of the repair companies.

In combination with the costs for the repair of the components (see **Fehler! Verweisquelle konnte nicht gefunden werden.**) the details are useful for estimating the possibilities for lifespan extension under the given conditions.

Table 43 Likelihood of failure of components of a typical Desktop PC

Component	Likelihood of failure			
	Never	Rarely	Often	Very often
Mainboard		X		
Processor	X			
Processor cooler/fan		X		
Memory			X	
Graphics card		X		
Power supply / fan			X	
Hard drive				X
Optical drive (CD/DVD)			X	
Integrated controller	X			
Peripheral interfaces	X			

Component	Likelihood of failure			
	Never	Rarely	Often	Very often
Housing	X			

Source: Our survey

The components of Desktop PCs that fail most frequently according to the repair companies include hard drives, optical drives, memory, and the power supply/fan (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). This is due mainly to:

- Thermal effects,
- Wear and ageing processes.

Desktop PCs are designed for a wide range of general uses, such as surfing the Internet, working with common office, mail and multimedia applications, or 3D-support for games. Desktop PCs are also very flexible with regard to replacing or upgrading individual components, and adapting the hardware configuration to meet specific requirements. The lifespan may be limited if the construction limits the scope for upgrading, for example in sub-categories such as Nettops or Thin Clients.

Nettops (Mini-PCs) were mainly developed for usual Internet use (e-mail, surfing, videos, online-games) as well as for basic office applications. A Mini-PC (without monitor and keyboard) will as a rule not exceed a weight of 5.0 kg (including any external power supply) and a housing volume of 5.0 litres.

Thin Clients are designed for a more limited application spectrum than Desktop PCs. They are more basic because they are integrated in networks and many computing operations are carried out on a central server. Even the booting of the operating system is carried out on the server. The hardware requirements for Thin Clients are thus less than for Desktop PCs.

In contrast, mini-PCs are independent computers, but with limited scope for upgrading and retrofitting compared with normal Desktop PCs.

6.5.2 Functional obsolescence

If a Desktop PC has an older motherboard, there are frequently compatibility issues with new components, which can make it necessary to exchange the older hardware. Older graphics cards are mostly no longer compatible in terms of their connections. For example, an AGP card cannot be connected to a PCI slot[75].

PCI-Express graphics cards, which were introduced in 2004, are downwards compatible, but without then offering additional performance. Attention is also paid to interoperability in the case of USB ports for peripherals. A USB 3.0 port can also be used by appliances designed for USB 1.0/2.0, although again with limited performance.

Limitations on compatibility are encountered when the processor has to be replaced to meet increased demands. It is necessary to weigh up the increased performance against the suitable processor types. In this context, a limiting factor is the availability of Bios updates for newer processor generations that are compatible with the mainboard (Heise 2014).

[75] Accelerated Graphics Port (AGP) is a high-speed point-to-point channel to attach a video card to a computer system, mostly to accelerate 3D computer graphics.
Peripheral Component Interconnect (PCI) is a bus standard for the connection of peripherals to the chipset of a processor.

Further functional factors that can lead to the replacement or exchange of Desktop PCs are included in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

6.5.3 Economic obsolescence

Fehler! Verweisquelle konnte nicht gefunden werden. shows costs for labour and parts for the repair of Desktop PCs according to the repairers and specialist journals (Heise 2014). The failure of a mainboard or processor can make a repair economically unviable in comparison with the cost of a new product. The costs for repairing or replacing memory chips, hard drive, power supply or graphics cards are considerably lower.

Table 44 Repair costs for a laptop

Component	Labour costs	Cost for parts	Time taken
Mainboard	≥ € 40/hour	€50-500	Depends on layout
Processor	≥ € 40/hour	50-500 €	30 min.
Processor cooler/fan	≥ € 40/hour	≥ 20 €	20 min.
Memory	≥ € 40/hour	≥ 30 €	10 min.
Graphics card	≥ € 40/hour	≥ 30 €	30 min. + driver
Power supply/fan	≥ € 40/hour	≥ 25 €	20 min.
Hard drive	≥ € 40/hour	≥ 39 €	Depends on size
Optical drive (CD/DVD)	≥ € 40/hour	≥ 25 €	15 min.
Integrated controller	≥ € 40/hour	-	see Mainboard
Peripheral interfaces	≥ € 40/hour	-	see Mainboard
Housing	≥ € 40/hour	≥ 30 €	Depends on layout

Source: Our survey

6.6 Causal analysis – Printers

6.6.1 Material obsolescence

6.6.1.1 Examples from the media: Ink pad reservoirs for ink-jet printers

In media reports on planned obsolescence, reference is often made to “programmed printer death”. The background is that shortly after the warranty period has expired, some ink-jet printers report that the printer would have to be serviced, or should not be used in its current condition (cf. Arte 2010).

Critics note that after a certain number of printed pages or printing operations[76], the software control stops ink-jet printers from functioning. The background is that the jets of the printer head have to be cleaned from time to time. The printer flushes a minute amount of ink through the printer head, and this ink is then diverted into a reservoir. This reservoir or waste-ink pad consists of an absorbent pad, designed for a “normal” printer lifespan. In most cases, the

[76] Some laser printers have a similar counter that reports, e.g. after 50,000 printed pages, that the appliance must be taken to customer service for maintenance (http://www.struzyna.de/Drucker-Reset.html).

saturation of the pad with ink is not actually determined by a sensor; a “drop counter” ensures that the capacity of the reservoir is not exceeded. If the ink were to overflow it could lead to further damage (e.g. to furniture, carpets, etc.)[77].

The drop counter is usually installed in the printer in the form of a serial EEPROM component[78]. For many manufacturers and models there are instructions on the internet showing how to reset the counter[79], i.e. disable the security function. The printer can then be used, but with the risk that ink may leak out. Typical instructions to reset the counter are as follows[80]:

- Switch off the printer.
- Press down the Resume button.
- Press down the Power button.
- Hold down both buttons for five seconds.
- Release the Resume button.
- Press 2x on the Resume button.
- Release the Power button.

“Programmed printer death” is therefore related to protective measures that are intended to prevent further damage and soiling. The drop counter cannot be regarded as a cause of “planned printer death”. Nevertheless, a critical inspection shows that other technical options could have been chosen. Exchangeable containers could be used for the residual ink, like those installed in products in the medium price range. Furthermore, consumers are often not aware of the limited capacity of the ink-pad reservoir when making their purchase.

6.6.1.2 Literature review

A study of the literature showed critical material factors for printers. The most frequent sources of faults are (WRAP 2013)[51]:

- Connections and hinges of the housing cover of the multi-function printers – material fatigue due to frequent use,
- Scanner lid and hinge, paper drawer of multifunction printer,
- Electrical connections are only fixed by plastic connections and will be damaged by power spikes (all product classes),
- Overheating,
- Blocked ink jets (in ink-jet printers).

Other factors include[81] (see also Section 6.6.1.1):

[77] Source: http://www.druckerchannel.de/artikel.php?ID=3285&

[78] EEPROM - Electrically Erasable Programmable Read-Only Memory

[79] See e.g. http://www.struzyna.de/Drucker-Reset.html

[80] Source: http://www.druckerchannel.de/artikel.php?ID=2744&seite=7&t=schritt_1_zaehler_zuruecksetzen

[81] Source: http://struzyna.de, www.murks-nein-danke.de

- EEPROM chip (drop counter).
- Ink pad reservoir.

The effect of blocked jets on the working life of printers depends on whether the print head is installed in the printer or is integrated in the ink cartridge:

Ink drying in the jets of the printer head can lead to a deterioration in the printing quality and in the worst case the whole printer head will have to be replaced. Cartridges with an integrated printer head cost more, but above all offer advantages if used for infrequent printing. The integrated printer head is automatically renewed every time the cartridge is replaced. This can extend the lifespan of the printer (EcoTopTen 2015).

If the print head is installed in the printer, there are two possibilities in the event of a defect (EcoTopTen 2015):

- The print head is installed in the printer and can be exchanged independently of the ink cartridge. Manufacturers recommend a regular exchange, e.g. after printing a certain number of pages.
- The print head is integrated in the printer and can only be exchanged by a specialist. In some cases, the print head cannot be repaired at all, so that a new printer is required.

6.6.1.3 Expert interviews

According to one of the manufacturers who was interviewed, the design of a printer with a long lifespan is influenced mainly be the following components:

- In the case of electrical components:
  - The ratings chosen for electrolytic capacitors,
  - Fan cooler;
- In the case of mechanical components:
  - Gears, motors, connections, drums, and belts,
  - Casing elements, buttons and keypads,
  - Display units, transmission belts and drums, fuser unit.

According to same manufacturer, the components of a printer rarely fail within their internally defined product lifespan of five years. No further details were given about the likelihood of failure of individual components.

A further manufacturer, who gave no details about internally defined lifespans, stated that mainboards very frequently fail (≥ 5% likelihood of failure), while power supplies and fan fail frequently (1% to 5% likelihood of failure). According to the manufacturer, such failure would not lead to the end of the product lifespan because these components can be replaced or repaired.

6.6.2 Functional obsolescence

In some cases, when a new operating system is introduced, updated driver versions are no longer provided for older printers and scanners. Users are then unable to continue using the old product in the way they were accustomed to, or the product is limited to a rudimentary operability.

As an illustration, the drivers originally supplied under Windows XP were used with TWAIN interfaces for printers, scanners and other peripheral appliances. After the upgrade to Windows 7, with the new WIA interfaces, the drivers that were supplied only offered full functionality for newer products. WIA-compatible drivers are not included for older products, so that scan and print functions no longer worked satisfactorily under Windows 7 (comment in an interview).

6.6.3 Economic obsolescence

A study by Oe*ko-Institut* has shown that the life-cycle costs of multifunction products (over a lifespan of 5 years) depends to a large extent on the costs for toner (ca. 65 %) and paper (23 – 38 %). The electricity costs account only for 1 to 2 %. And the original purchase cost only accounts for 5 to 10 % (Oeko-Institut 2013). The high costs for ink or toner depend on the consumption but also on the costs for purchasing new ink cartridges or toner cartridges.

The comparatively high running costs suggest a reason for the premature replacement of products, namely when the purchase of ink cartridges/toner cartridges or the repair of the product would cost much more than the purchase of a new printer. This reflects a typical sales strategy for printers in the consumer sector. The printer itself is relatively inexpensive, while the ancillaries are expensive.

Alternative providers of cheaper printer ancillaries have meanwhile gained a share of the market (**Fehler! Verweisquelle konnte nicht gefunden werden.**), although the quality of the ink is a matter of dispute, in particular if the refill ink has not been degassed, so that air is introduced into the printer head[82]. According to EcoTopTen (2015), however, alternative inks can give satisfactory results in quality tests (see also Stiftung Warentest 2015), and sometimes even do better than the original inks. They are often as resistant to fading in sunlight as the original inks. But generally, the highest print quality is achieved with the original inks from the printer company. If the third-party inks are of a poorer quality, then it is important to weigh up the possible savings against the loss in quality[83].

Stiftung Warentest points out that there are no grounds to fear a loss of warranty cover as a result of using alternative cartridges. Problems can only arise if damage can be shown to have been caused by the alternative cartridge. In such a case it would also be possible to lodge complaints with the manufacturer of the alternative cartridge (EcoTopTen 2015).

Alternative cartridges are not available for every printer. It is more difficult to produce an alternative if the original cartridge contains a drop counter chip or the cartridge is patent protected (EcoTopTen 2015).

[82] http://www.hitech.bfh.ch/de/archiv/hitech_32013/focus/labor_entgasungsstation_fuer_inkjet_tinten.html; Accessed: 18.11.2015

[83] See quality tests in Stiftung Warentest (2015), Stiftung Warentest (2014c) and Stiftung Warentest (2012)

Table 45 Ink and toner costs for original and other suppliers

	Costs per text page in eurocent		Cost per A4-photo in eurocent	
	Original	Others	Original	Others
Ink	5.5	2.7	152.1	62.8
Laser toner	4.0	2.3	97.5	56.7

Source: EcoTopTen (2015)

6.7 Causal analysis – Washing machines

6.7.1 Material obsolescence

6.7.1.1 Examples from the media: Plastic suds containers in washing machines

In the media, the use of a plastic suds container instead of stainless steel container is often cited as a typical example of planned obsolescence in washing machines:

Example 1: *"A further case of a planned short life was found in the RUSZ repair and service centre (www.rusz.at) for low-price washing machines. Plastic is used for suds containers instead of stainless steel. The bearings cannot be easily replaced like in high-end machines, but are press-fixed. And these bearings fail within a few years – because the shock absorbers are too weak for the 1600 revolutions of this product. That means that in the foreseeable future the whole suds container would have to be replaced. But of course nobody does that"* (David-Freihsl 2012).

Example 2: *"Almost all washing machine manufacturers have replaced the steel suds containers in which the drum rotates with plastic suds containers. The lower resilience of the material leads to hitherto unknown damage, causing expensive repairs, and finally the total writing-off of the product, with a marked reduction in the lifespan. The support for the bearing was changed (press-fitted into the plastic container instead of using a cross piece)"* (Schridde et al. 2012).

Additional information: *"The relatively unstable bearing supports in the plastic suds container lead in particular for front loaders to dynamic leaks of the drive shaft seals and as a result to corrosion of the bearing. It is then possible that the drum bearings are defective within only a few years, despite seeming to be more than strong enough, whereas washing machines with a cross piece support are often still showing no signs of weakness after 20 years. A repair is hardly possible without replacing the rear half container and is as a rule not worth it if a new part is used"* (Schridde et al. 2012).

Example 3: *"A washing machine with plastic suds container often lasts for little more than 3 years. With a container of stainless steel, the lifespan can be 20 years or more. The material of the container can often be checked by pulling the door seal slightly to one side"* (KONSUMENT 2/2013).

Plastic suds containers are often made of fibre-glass reinforced polypropylene. The main properties of polypropylene are (Licharz, no date):

- Lower density than other materials (0.91 g/cm^3),
- Minimal water absorption (< 0.01%),
- Excellent chemical resistance to solvents,

- High corrosion resistance,
- Relatively high surface hardness,
- Very good electrical insulator,
- Physiologically unremarkable.

Asked about the reliability of plastic suds containers in washing machines, experts from the domestic appliance manufacturers responded that “metals are also being replaced by plastic in other parts of industry, e.g. fuel tanks in road vehicles, vehicle bodywork”. Asked whether the plastic components can be designed to be just as reliable as components from (stainless) steel, an expert replied: “Yes. But the design, above all relating to structural mechanics, chemical durability and thermal burden, is fundamentally different from metals. It is crucial to have sufficient expertise in the design of plastic components that are exposed to high mechanical forces. On the basis of calculations and simulation, together with many years of experience in the design of plastic components and the use of suitable verification methods (test and analysis), the company X (anonymised) is in the position to design plastic components that meet the specifications. Since the early 1990s, this company has been using a specially developed plastic for suds containers. This has proved to be very reliable over many years. The use of plastics not only offers cost benefits, but also various other advantages according to the participants:

“Compared with containers made of stainless steel, plastic containers offer various advantages:

a) With plastic containers there is no corrosion.

b) The acoustic properties of the product are improved.

c) With plastics the thermal losses are lower.”

The independent tests of the lifespan of some 600 washing machines (Section **Fehler! Verweisquelle konnte nicht gefunden werden.**) carried out by Stiftung Warentest over 15 years (=196 models, with three appliances per test) show that only a few machines had problems that could be attributed to a plastic suds container[84]. It can be assumed that some 90% of the tested machines had a plastic suds container. However, Stiftung Warentest only tested machines costing more than € 350.

The claim that the use of plastic for the suds container leads to a planned obsolescence is therefore not confirmed.

6.7.1.2 Scientific studies / Test reports

Stiftung Warentest

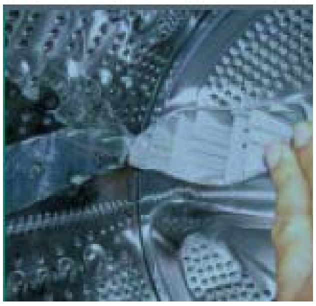
Fehler! Verweisquelle konnte nicht gefunden werden. shows a summary of the results of the lifespan investigations of washing machines carried out by Stiftung Warentest over a 15-year period (2000-2014). In these tests, problems were identified that had limited the lifespan of the washing machines. A total of some 600 washing machines were tested, with 196 different models.

[84] Of these 196 models, 41 models had problems during a 10-year test that led to an ‘unsatisfactory’ assessment of the lifespan.

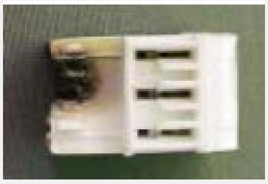
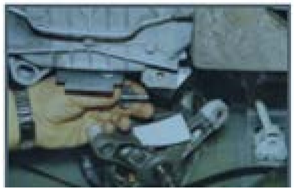
Table 46 Results of lifespan tests on washing machines (2000-2014)[85]

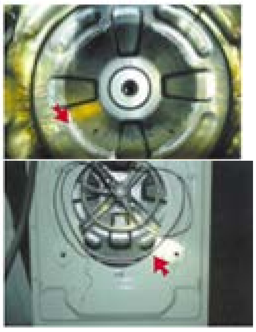
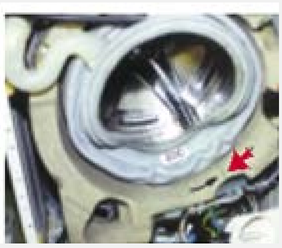
Year published	Number of machines in test	Name of appliance	Lifespan problem	Image (if published)
2014/11	13	LG F 14A8QDA	Rubber parts leaked	
		Gorenje W 8544 T	Two machines failed in the first half of the duration test due to loose insulation material	
		Beko WBB 71443 LE	Half way through the duration test, 2 machines failed with electronics damage	
		Bauknecht WA Plus 784 DA	3 x Start button broken	
2013/11	12	Haier HW80-B1486	1 of 3 failed due to bearings damage and other problems	
		Gorenje W7543 T	Water inlet hose showed friction wear	
2013/1	13	Gorenje WA 72149	Unknown	
		Candy EWO 1483DW	Water leak	
2011	14	Gorenje WA 72147 AL	2 of 3 failed with motor problems	

[85] Our collocation, Source: Journal test by Stiftung Warentest

Year published	Number of machines in test	Name of appliance	Lifespan problem	Image (if published)
		Haier HW70-BW140	2 of 3 failed with a hole in the hose connecting detergent draw and suds container	
2010	14	Candy GO 1460D	Drum casing opened and destroyed the entire machine	
2009	10	Bauknecht WA pure XL	Hole in door seal	
		LG F1403 TD	Loose fan + defective heating element	
2008	13	Bauknecht WA Pure XL 12 BW	Electronic problems	
		Blomberg	Electronic problems	
		AEG-Electrolux Lavamat 72850	Leak from suds container	
2007	11	LG WD-14370 FD	Programme stopped	

Year published	Number of machines in test	Name of appliance	Lifespan problem	Image (if published)
		Bauknecht WA Pure 14 Di	Fault in switch	
		Samsung WF-B146 NV	Door spring broken	
2006	15	EBD WA 3112	Electronic problems	
		Indesit WIE 127	Ballast weight fixture loose	
		Samsung B 1245 AV	Drum casing opened	
2005	11	Bauknecht WAK 8788	Heating element worn by drum	
			Contact broken on heating element	
		Blomberg WAF 1340 A	Carbon brushes faulty	
		Ariston AWD 149	Temperature sensor broken and contact problems	
2004	10	Bauknecht Dynamic Sense WAL 10988	Minor problems with control	
		Blomberg WA 54611	Minor problems	
		Candy Tempo Logic CBL 160 PDE	Minor problems	
		LG intellowasher WD 16220 FD	Minor problems	
2003	12	Foron WF 1596 A	Heating charred	

Year published	Number of machines in test	Name of appliance	Lifespan problem	Image (if published)
2002	15	AEG 84740	Connection element charred	
		Bauknecht WAP	Motor faulty	
		Brandt	Plastic parts broken	
2001	16	Bauknecht WAT 9565 WP	Water damage and other problems (motor, crack in cement weight)	
		EBT TL 2247	Water damage and other problems	
		Hoover T225E/1	Bearing damage and other problems	
		Candy ActivaCTA125 DE	Leaks and bearing problems	

Year published	Number of machines in test	Name of appliance	Lifespan problem	Image (if published)
		Foron Vitatop WN 1243 N	Leaks in 2 machines, cement weight broken	
		Zanker FR 2921	Vibrations, Baffles broken (1 appliance)	
2000	17	Constructa Viva 1000	Drum cross piece broken (1) – Belt fell off (1)	
		Bauknecht WA 7575 W	Heating element defective (2) – bearing (1) – Drum cracked (1) – suds container leaked (1) – Weight cracked (1)	

The detailed analysis of the causes of failures hardly shows any recurrent failures. Practically all elements of a washing machine can lead to failure. In particular, the components that are most exposed to vibrations (all parts attached to the suds container) seem to fail more often than other parts.

WRAP analysis

The WRAP research institute investigated the robustness requirements for washing machines in 2011 (WRAP 2011c)[51]. The aim was to develop buying specifications for washing machines to assist buyers and manufacturers and to identify products that last longer and can be more easily repaired, in order to reduce environmental impacts. WRAP draws on extensive surveys in the repair industry and has identified the following points that could shorten the lifespan of washing machines:

- Problems with the electronics, in particular with the circuit boards due to fluctuations in the mains power supply or due to leaks after poor installation of the washing machine or blockages in the soap drawer or inlet and outlet pipes,
- Door seals and hinges,
- Inlet and outlet hose pipes,
- Water heating elements,
- Drum bearings (due to water leaks),
- Motor (wear of brushes),
- Soap drawer (improper use or detergent lumps causing blockages),
- Motor and drum bearings (due to overloads).

The study did not analyse the types of faults or set any priorities that would make it possible to draw conclusions about planned obsolescence.

WRAP (2011c) considers how environmental impacts can be reduced by the production of machines that last longer so that fewer new machines have to been produced. The most beneficial measures for extending the product’s life are specified, some of which are relatively easy to achieve.

The case study assessed the Bosch Avantixx 6 VarioPerfect and the Siemens IQ-700, and focused on key aspects contributing to durability and repair. Both machines have an "A" energy rating. The Siemens washing machine is guaranteed leak-proof and has a five-year parts and labour guarantee. The Bosch machine has a two-year guarantee. The Siemens IQ-700 costs about EUR 800, compared with some EUR 395 for the Bosch Avantixx 6 VarioPerfect.

The study found that both machines were robust, very durable, and offer simple and effective access to key parts for repairs and replacements. Clear step-by-step instructions to replace parts such as the motor or drum are available for qualified repairers. Other parts such as the door and seal can easily be replaced by the user with the online user manual.

In all, both appliance offer easy access to internal parts from the top or rear. Motor, concrete block and dampers are bolted securely in both models, preventing damage by vibrations.

The Siemens model has additional damping material that effectively reduces vibration during use. In both models it is relatively easy to replace circuit boards, hoses, and drive belts. Repairs are made easier by the use of only the necessary types and numbers of fixings such as screws, bolts, cable routing systems, and snap fits.

The study listed key features that would be easy to replicate:

Access to information to avoid and diagnose faults:

- Good design, in order to avoid mechanical damage;
- Robust and corrosion-resistant housing;
- Damping to reduce the effects of vibrations during operation;

- Well-secured internal components, with a combination of bolts and lugs;
- Sensors and electronic controls to reduce vibrations and wear.

Robust electrical design:

- Low-maintenance, brushless motors;
- Leak protection for vulnerable parts such as circuit boards;
- Wiring held in place by clips;
- Shorter leads to minimise risks of breakage;
- Parts well protected against potential internal leaks.

Ease of access and availability of spare parts for repairs:

- Large rear and top covers affording easy access;
- Fixing with a minimum number of standard screws and bolts;
- Internal clips and connections that are easy to operate;
- Availability of spare parts at reasonable prices, so that repairs can be carried out beyond the warranty period.

Retailers and manufacturers should offer as many of these functions as possible within price constraints. The study concludes that companies that want to produce machines offering environmental benefits and better brand differentiation should aim to provide durable, higher-quality products with longer lifespans.

6.7.1.3 Expert interviews

Recent decades have seen a significant change in the construction of almost all domestic appliances, away from electrical appliances with motor, heating and switches towards electronic appliances with microprocessors, sensors and digital displays. Such changes also lead to different failure behaviour of the appliances.

Changes due to the introduction of electronic components

Electrical parts and components such as mechanical switches, bimetallic thermostats, press buttons, relays, etc. are often operated at the mains voltage with high currents (up to 16 A in the household), whereas in contrast, integrated electronic components can combine various functions and work at low voltages (a few volts).

With electrical components it is important to provide adequate clearance and creepage spacings in order to avoid failures and short circuits. But even then, moisture, dust, fluff, etc. can easily cause problems. In contrast, electronic sensors and microprocessors can be placed much closer together, and functions can be integrated on a semi-conductor chip or a circuit board. This in turn reduces the numbers of plug contacts between individual parts and components. The integration on one component also makes it possible to carry out thorough testing of the components before they are installed in an appliance.

However, the experts also see disadvantages in the use of electronic components and processors. Semiconductor devices consist of layers of silicon with differing conductive properties. The spacing of these structures has been reduced considerably over the years. In the 1980s, 90 nm layers were usual, but now they have thicknesses of only 16 nm. The miniaturisation of semi-conductors has led to a rapid increase in the information that can be stored. According to Moore's Law the complexity of integrated circuits doubles approximately every 2 years.

But the miniaturisation of structures can pose a risk: as a result of thermal diffusion or through externally induced disturbances of the atomic lattice of the semi-conductor, stored information can be lost and the device can fail.

The effects are well-known, and so electronic components are available in a range of ratings, appropriate for the conditions under which they are to be used (in particular the temperature range). However, components with lower failure rates at higher temperatures can be much more expensive. In principle, increased testing of components and integrated circuits could identify potential causes of failures, so that these could then be eliminated – however this would again affect the costs and prices, as experts of a leading domestic appliance manufacturer emphasised. Sometimes the specifications for electronic components match those otherwise only required for military applications.

Stability of the power supply

Fluctuations in the supply voltage can also cause the failure of appliances. In particular, the increased amounts of power fed in from photovoltaic panels and from wind-power generation pose considerable challenges for distribution networks. The power supplies in Germany are nominally 230 V / 50 Hz, but EN 50160 initially specified that the 10-minute mean of the supply voltage should lie in the range 230 V +/- 10% for 95% of the time. That means that for 5% of the time it can be outside this range, and that there can be overvoltage peaks within any 10 minutes. The 3rd edition of EN 50160 specified that 100% of the voltage values must lie in the range +10%/-15% of the nominal voltage, but according to the German Federal Network Agency there are virtually no measurements that show that these values are always complied with for all households. The Institute for Electrical Power Systems and High Voltage Engineering of TU Dresden confirms, however, that "In particular with a lot of photovoltaic (...) it is possible that the upper limit of +10% Un [*nominal voltage of the system*] will occasionally be exceeded for short periods."

Asked about the influence of voltage characteristics (voltage level, transient overvoltage, flicker, etc.) on the possible failure of an electrical/electronic appliance, the expert from Dresden explains: "It is necessary to distinguish between reversible and irreversible damage. There is also a distinction between the immediate failure of a product and a cumulative reduction in the lifespan. Practically all electrical energy quality limitations (power frequency over-voltages, higher-frequency emissions, unbalance, etc.) place additional burdens on the product which in many cases result in additional thermal impacts and can therefore lead to lifespan reductions. More extreme deviations, both short-term (overvoltage) or long-term, can lead to immediate failures. Voltage outages will not as a rule lead to failures, but they can cause reversible damage. The quantification of lifespan reductions is very complex and so far, little research has been carried out on this."

Asked whether the definition of EN 50160 is adequate to reliably exclude impacts on the lifespan of appliances, the expert from the Institute of Electrical Power Systems and High Voltage Engineering der TU Dresden commented: "The EN 50160 is a product standard that describes the voltage characteristics of the distribution networks. It is not itself a standard for the design of appliances, although such standards should orient themselves on EN 50160. Furthermore, the appliance manufacturers must ensure that they use components that have the appropriate electromagnetic compatibility. This must be coordinated by both the interest groups in order to achieve a macroeconomic optimum. In view of the probabilistic coordination, it is necessary to be aware that in rare cases the compatibility level could be exceeded for short-periods. A deterministic coordination would lead to considerably increased costs for both network operators and appliance manufacturers. It does not make sense to limit the voltage range too strictly, nor to place unnecessarily high demands on the electromagnetic compatibility of products. I think that EN 50160 represents a good compromise. It is very difficult to completely exclude affects on the lifespan. This requires a considerable amount of future research."

However, the expert of the Institute of Electrical Power Systems and High Voltage Engineering der TU Dresden still sees a need for further action: "Maintaining a constant product quality, both on the part of the network operator and the product manufacturer is in my view an important precondition for ensuring permanent electromagnetic compatibility. Before limits are made more stringent, it is first necessary to close existing gaps. The applies in particular for the 2–150 kHz frequency range, for which limit values scarcely exist although disturbances are becoming increasingly common. Manufacturers of domestic appliances should not assume that the power supply will always have a voltage of 230 V +/-10% with a perfectly sinusoidal 50 Hz frequency, but should allow for voltages outside the upper and lower limit values and make sure that these do not lead to the failure of the products. In particular, it should be taken into account that the supply voltage can have a significant proportion of harmonic distortion that should be filtered out as far as possible in order to avoid damage to the product. Appropriate limit values should be developed in cooperation by extensive investigations of existing supply networks and the potential damage to appliances."

Designing products for a defined lifespan / Number of cycles

Miele confirmed that "the defined technical lifespan for the design and development of washing machines … for Miele is 5,000 programme cycles, which corresponds to about 20 years in a normal household". On the basis of trials in test households, the choices of programmes and the settings for the individual programmes are determined. A statistically significant number of machines then go through appropriate tests before the series is launched on the market. A very low failure rate of the tested machines is required before the series is released (only reparable faults are allowed). In addition, parts and components that are particularly exposed during operations are tested individually to ensure a satisfactory lifespan under conditions that come as near as possible to the real use.

The specifications for suppliers are also based on the lifespan requirements for the washing machine, and parts are tested both individually and in the machines. But Miele also notes that "many errors that lead to early failures … are due to a lack of experience in design and testing. It is only possible to gain experience if there is sufficient testing and simulation in advance so that potential early failures can be eradicated. Extensive field experience with ones own machines form an important basis for ensuring a long lifespan. The lack of field experience soon leads to increased failure rates as a result of unexpected errors."

According to Miele short-lived washing machines differ from their own machines "… mainly in the specifications for critical parts: drum bearings, the mounting for the suds container, shock-absorber ratings and fixings, the bearings of the motor and pumps, and the design of seals and the materials used for them. In addition, it is possible to cut costs when designing and choosing materials for parts that carry water."

Other leading brands, e.g. BSH, Whirlpool and Electrolux, set a target for the lifespan of "200 wash cycles per annum x 10 years" (see also http://www.spiegel.de/karriere/berufsleben/ingenieure-entwickeln-waschmaschinen-fuer-die-zukunft-a-927797.html; 16.10.2013). “After reaching 2000 wash cycles it is advisable to replace the machine. Over this period, technological advances will have been made, with improvements in water and power consumption, and new wash programmes introduced to meet the wishes of our customers”, explains Marten van der Mei, CEO of Whirlpool Corporation Germany.

It was not possible to determine within the scope of this project whether other manufacturers set themselves a much lower lifespan for washing machines as their target, but the results of the duration tests carried out by Stiftung Warentest every year suggest that this is not the case, since non of the manufacturers regularly failed the duration tests. However, the tests did not cover all the market, since machines costing less than €350 have not been tested.

According to the manufacturers who were questioned (see above) components of their machines fail ‘rarely’ or ‘never’ and failures can all be repaired. The responses also made clear that there are ways to subject both components and complete machines to a test of durability requirements. However, such tests are not binding, so that it is not ensured that they will be carried out in full by all suppliers with sufficient frequency. For standard components, it could be appropriate to specify the test regulations. But for parts produced specifically for one manufacturer it would only be possible to test compliancy with durability requirements in special test facilities.

Summary of the expert opinions

According to the experts, domestic machines are designed for a certain period of use or for a number of washing cycles, and appropriate tests can be carried out to check that the products meet these specifications. Requirements differ considerably from one manufacturer to another and this is also reflected in the retail price of the machines. However, since the price not only reflects the materials used, but also the services provided, the provision of spare parts, additional uses, the design, and other factors, it is not possible to establish a strict relationship between price and lifespan.

Machines can fail prematurely in the event of disturbances to the power supply. In the opinion of one of the experts interviewed there is a gap here both in the causal research and in the regulatory cover.

6.7.1.4 Results of the internet-based consumer survey

Responses are included from the 736 participants who had recently disposed of a washing machine.

New or second-hand washing machine

76 percent der participants said that the washing machine they last disposed of had been bought new; 23 percent of the participants had bought their previous machine second-hand (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 47 Number of washing machines bought new and second-hand

Did you buy the washing machine new or second hand?	Frequency	%
New	559	76.0
Second-hand	170	23.0
I don’t know.	7	1.0
Total	736	100.0

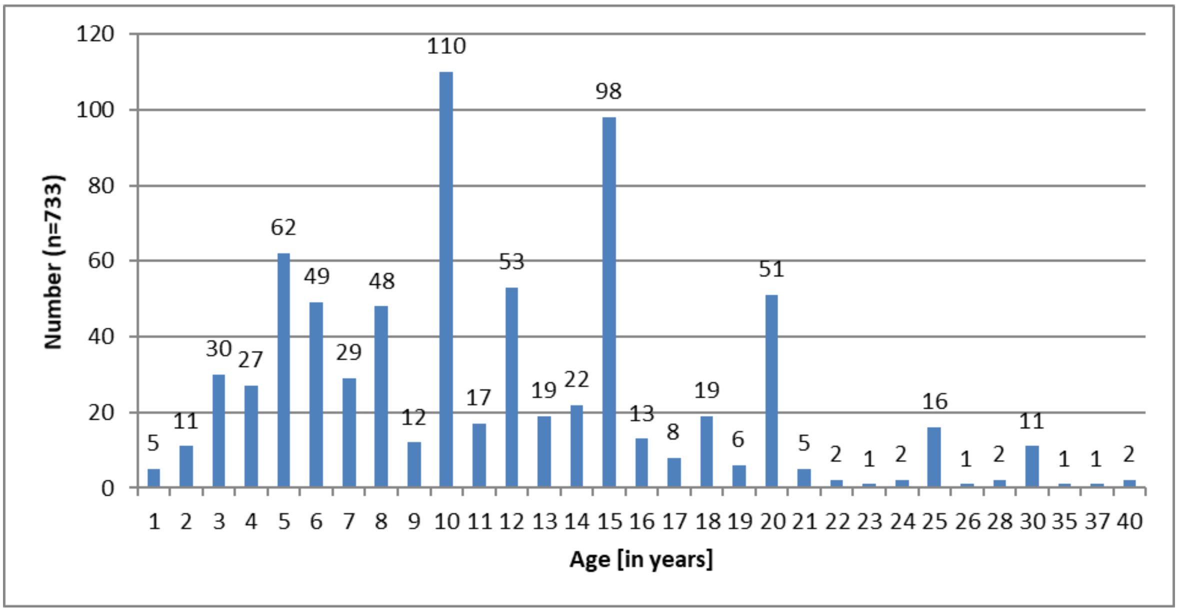
Age of the washing machine

The washing machines had a mean age of 11.6 years, with a standard deviation of 6.3 years. The youngest washing machine was one year old, the oldest 40 years. More than 50 percent of the washing machines up to 10 years old (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Figure 77 shows the age distribution in years. There are noticeable peaks for 'round numbers' (10, 15, 20 etc.) This can be attributed to vague recollections about past events.

Table 48 Age distribution of the washing machines

How old was the washing machine?					If you do not know, please estimate a value [in years].			
N	Mean	SD	Min.	Max	25th percentile	Median	75th percentile	Range
733	11.6	6.3	1	40	6	10	15	39

Figure 77 Age of the washing machines



Source: Our presentation

Price of the washing machine

Participants were not asked to state the exact price they paid because in most cases some time had passed since the purchase, and price developments also made comparisons difficult. They were asked to choose between "an inexpensive appliance (no name), "a medium-priced appliance", or "an expensive appliance (top brand)", or to answer "I don't know". More than half of the washing machines bought had been medium priced. Just over a quarter of participants purchased an expensive brand product, see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 49 Price of the washing machine

How expensive was the washing machine?	Frequency	%
An inexpensive appliance (no-name)	71	9.7

How expensive was the washing machine?	Frequency	%
A medium-priced appliance	397	54.0
An expensive appliance (top brand)	197	26.8
I don’t know	70	9.5
Total	735	100.0

Repair of the washing machine

Of 734 washing machines appliances, 42 % had been repaired at least once. Half the machines had never been repaired, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. In 58 cases, the participants were unable to give any details about repairs.

Table 50 Repair of the washing machine

Was the washing machine ever repaired?	Frequency	%
Yes	308	42.0
No	368	50.1
I don’t know.	58	7.9
Total	734	100.0

The 308 participants whose washing machine had been repaired were asked whether the repair was carried out during the warranty period. Of the 299 participants who answered this question, 13 % said that the repair had been carried out under warranty; 82 % said that the repair had been carried out after the warranty had expired (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 51 Repair under warranty washing machine

Was the repair carried out during the warranty period?	Frequency	%
The repair was carried out in the warranty period.	38	12.7
The repair was carried out after the warranty had expired.	244	81.6
I don’t know if the repair was carried out in the warranty period.	17	5.7
Total	299	100.0

Frequency of use of the washing machine

66 % of participants used the washing machine several times a week, 21 % used the washing machine once a week. In 11 % of cases the washing machine was used daily or several times a day (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 52 Frequency of use of the washing machine

How often was this washing machine used as a rule? If you do not know, please estimate a value.	Frequency	%
Once a month	12	1.6
Once a week	156	21.2
Several times a week	488	66.2
Daily	65	8.8
Several times a day	16	2.2
Total	737	100.0

Fate of the washing machine

64 % of the washing machines had been disposed of. 26 % of the machines were sold or given away, see **Fehler! Ungültiger Eigenverweis auf Textmarke.**.

Table 53 Fate of the washing machine

What did you do with the machine?	Frequency	%
Disposal	467	63.6
Passed it on (sold, given away)	193	26.3
Stored away	31	4.2
Some other option	43	5.9
Total	734	100.0

Reason for buying a new washing machine

Asked about their reason for getting rid of the washing machine, 69 % of the 733 respondents said that the washing machine was defect. In 10 % of cases, the washing machine was not energy-efficient enough, in 14 % there was some other reason (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The comparison of **Fehler! Verweisquelle konnte nicht gefunden werden.** and Fate of **the washing machine**

64 % of the washing machines had been disposed of. 26 % of the machines were sold or given away, see **Fehler! Ungültiger Eigenverweis auf Textmarke.**.

shows that fewer washing machines were disposed of than were defective.

Table 54 Reason for buying a new washing machine

Why did you get rid of the washing machine? Choose the most appropriate reason.	Frequency	%
The washing machine was broken.	503	68.6
I didn’t like the washing machine any more.	7	1.0
The washing machine didn’t have enough functions.	14	1.9
I was given a new washing machine.	29	4.0

Why did you get rid of the washing machine? Choose the most appropriate reason.	Frequency	%
I had another reason	104	14.2
The washing machine was not energy-efficient enough.	76	10.4
Total	733	100.0

Satisfaction with the lifespan of the washing machine

Asked whether they were satisfied with the lifespan of the washing machine, 68 % said that the lifespan had met or exceeded their expectations. 29 % of the participants were dissatisfied with the lifespan (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 55 Satisfaction with the lifespan of the washing machine

How satisfied were you with the lifespan of the washing machine?	Frequency	%
I don't know.	18	2.5
I was surprised how long the washing machine kept going.	132	18.0
The lifespan met my expectations	280	38.1
It was time to replace the washing machine with a new one.	88	12.0
I had expected to be able to use it longer.	135	18.4
The washing machine didn't last nearly long enough.	81	11.0
Total	734	100.0

Defect of the washing machine

503 participants who had said that the washing machine had had a defect were asked what this had been. Multiple answers were possible here. The most frequently mentioned reason was a fault in the electrics (28%), followed by the pump (23%) and damage to the bearings (15%).

Table 56 Defects of the washing machine

What exactly was wrong with the washing machine?	Frequency	%
Heating	34	6.8
Pump	115	22.9
Spin function	57	11.4
Electrics	142	28.3
Damage to bearings	79	15.7
Leakages	42	8.4
Door (hinges, seal)	18	3.6
Switch	23	4.6
Something else	50	10.0

What exactly was wrong with the washing machine?	Frequency	%
Don't know	105	20.9
Total no. of replies	665	132.5
Total no. of participants/appliances	502	100.0

6.7.2 Functional obsolescence

As a rule, the performance of a washing machine remains constant over its entire lifespan. However, other factors change. For examples, the textiles that are being washed change, not only as a result of fashion but also with the introduction onto the market of new fibres or new methods for finishing textiles. Detergents are also constantly undergoing changes. As a rule, consumers purchase detergent in amounts to last for a few weeks, but the next time detergent is bought it may already have different constituents and a different chemical composition. Innovations of detergents find their way onto the market much more quickly than innovations of the washing machines for which the detergent is purchased. The aim of an investigation of the domestic technology section of the University of Bonn was to determine how well washing machines of various ages harmonise with current detergents and whether old washing machines still provide good results with these new detergents. This aim could only be achieved by testing "real" old washing machines under current conditions. Such tests were carried out in 2004 with eight washing machines (Stamminger et al. 2005), between 9 and 29 years old that were used in households in and around Bonn (**Fehler! Verweisquelle konnte nicht gefunden werden.**). As a comparison, two nearly new washing machines (made in 2002 and 2004) were tested under the same conditions. Since the composition of the IEC-Test detergent (IEC 60456:2003) is nearly identical with that of compact detergents, only wash programmes without pre-washing were selected.

Table 57 Characteristics of the washing machines

Machine	Code	Year of construction according to consumer	Date of capacitor	Speed (rpm)	Drum volume (l)
AEG Öko-Lavalogic 1600	A	2002	2002	1600	48
Miele W754	B	1983	1983	900	39
AEG Domina F	C	1975	?	?	44
Privileg 40	D	1985	1984	400	35
Siemens Siwamat Plus 284	E	1988	1988	800	39
BBC Rodomat 81	F	1981	1982	800	38
AEG Öko-Lavamat Sensorlogic	G	1995	1995	1400	40
Bosch V 454	H	1992	1990	800	36
Miele de luxe W 442	I	1979	1980	1100	43

Machine	Code	Year of construction according to consumer	Date of capacitor	Speed (rpm)	Drum volume (l)
Miele Softronic W 2245	J	2004	2004	1600	42

In order to ensure comparability, all the washing machines were loaded with the same amounts of textiles. Loads weighing 4 kg were used in order to ensure that none of the machines were overloaded during the tests, which could have caused unrealistic problems with the washing performance. In addition, studies have shown that on average consumers only load their machines to about 3/4 of the maximum capacity (Kruschwitz et al. 2014).

Four test runs were carried out for each parameter and water and energy consumption as well as performance data were recorded. The washing performance was tested by creating artificially soiled areas on the washing and measuring the degree of whiteness afterwards (as usual when testing washing machines). A Wascator CLS washing machine was used as reference for calculating the index of washing performance and converting this to the washing performance class, as usual for EU energy consumption labelling (95/12/EC:1995). All other conditions followed international standards (IEC 60456:2003).

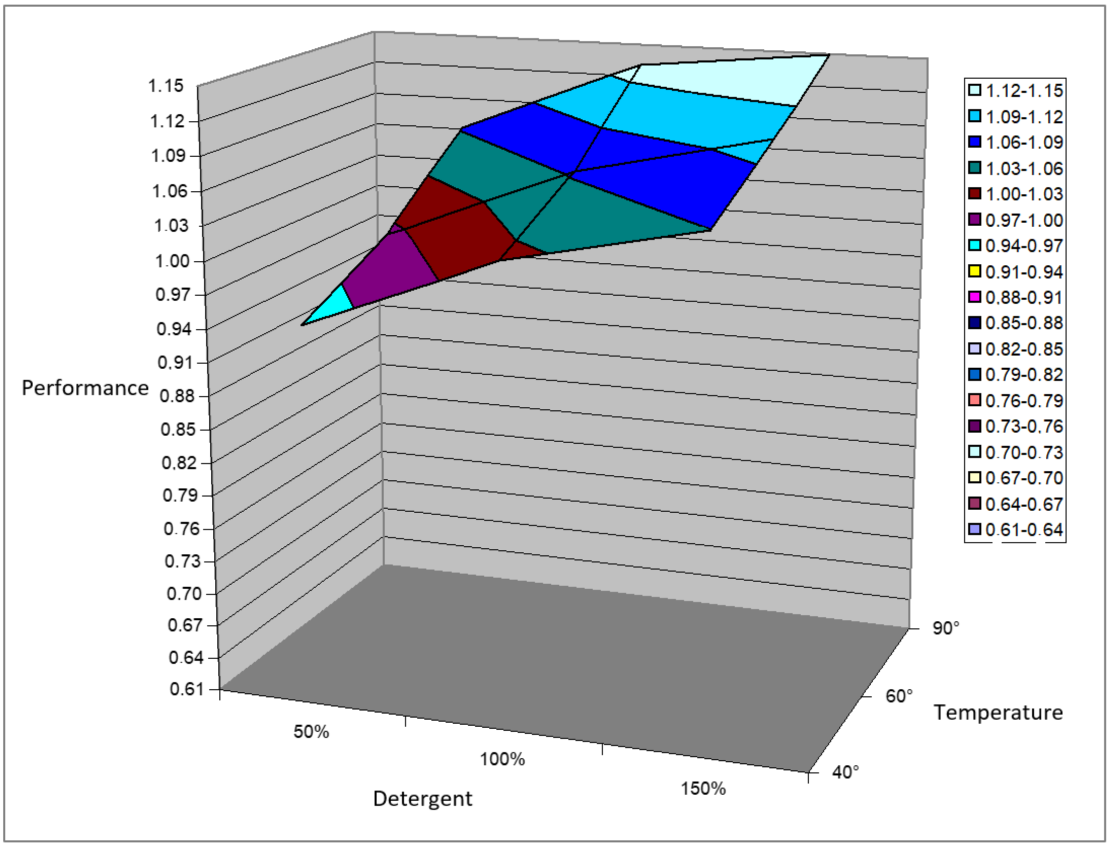
Tests were carried out with nominal amounts (100%) of detergent for cotton programmes at 40°, 60° and 90°C. In addition, the machines were operated with reduced (50%) and increased (150%) detergent doses using a 60°C cotton programme. This was to allow for the preferences of the user when adjusting the washing performance of their washing machine by selecting different temperatures or by varying the amount of detergent.

6.7.2.1 Test results

Results are presented with reference to the Index System and the Class definitions of washing performance from the first European energy consumption labelling (introduced in 1995), although the test conditions did not correspond to all the definitions for this system. A 3-dimensional presentation of the performance ranges of the washing machines depending on the amounts of detergent used and the chosen temperature gives the best overview of the results (Figure 78 and Figure 79).

The same performance is achieved in a 90°C programme with only 50% of the detergent dose, in a 60°C programme with a full detergent dose, or in a 40°C programme with a 150% detergent dose (Figure 78). The consumer can choose between these and obtain the same result. The only constraint is the temperature stability of the items beings washed.

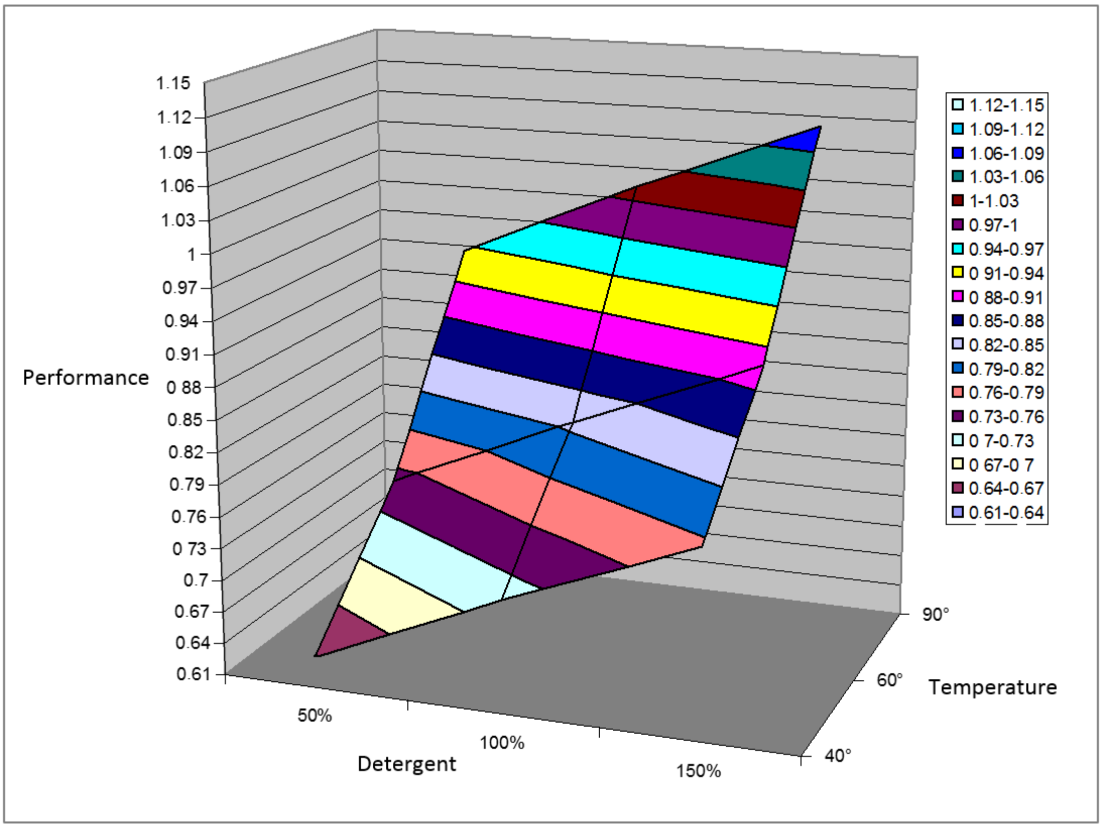
Figure 78 Index of washing performance of a new washing machine under various conditions[86]



Source: Our presentation

[86] Shaded areas represent classes of performance in accordance with the EU-Energy label. The washing performance of machines with reduced or increased detergent doses at 40° and 90°C are obtained by linear extrapolation.

Figure 79 Index of washing performance of a washing machine from 1975 under various conditions[87].



Source: Our presentation

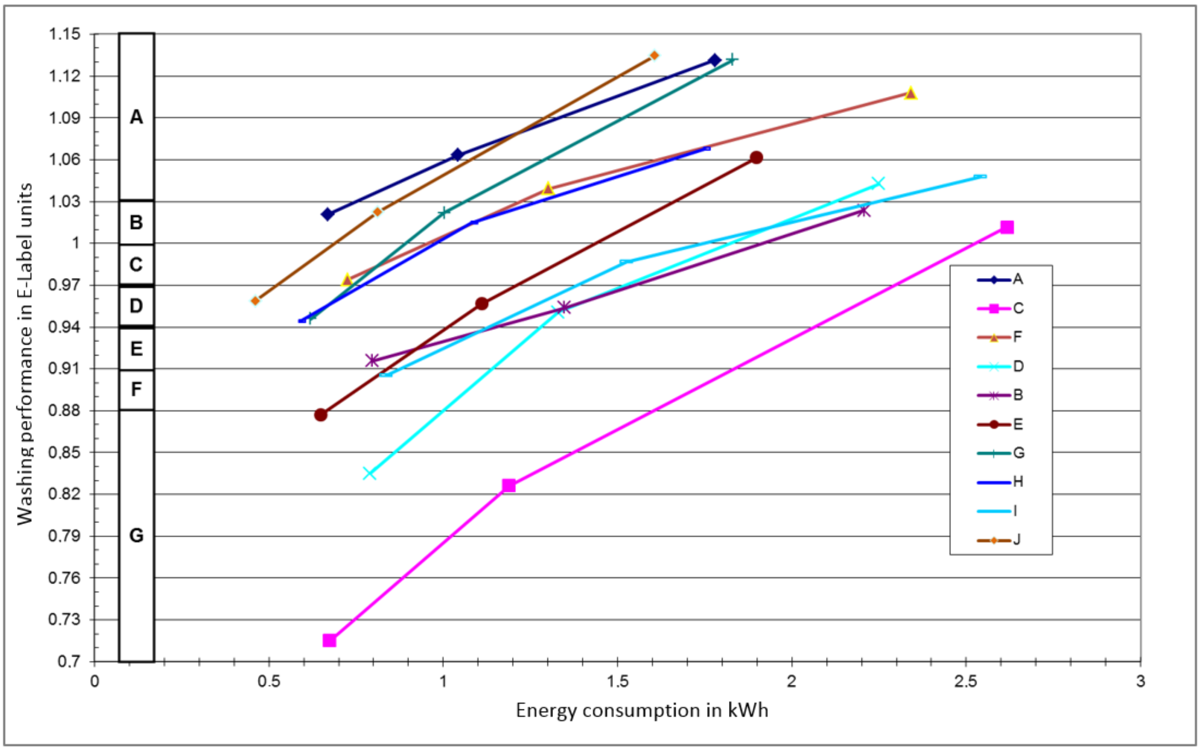
Some washing machines, in particular older ones, have similar performance ranges, but their absolute values are much lower and the gradients show an increased influence of dose and temperature on the washing performance (Figure 79). An overview of the measurements with the 60°C programme for cotton for all three amounts of detergent shows that the performance, which varies considerably between the machines, can in effect be adjusted by the detergent dosing. This is even clearer if the results for the washing performance are presented in energy label classes (95/12/EC), ranging from A (best) to G (very poor). Older machines rarely achieve Class A under standard conditions, in contrast to new washing machines, so that as a rule increased doses of detergent are required. There is also a marked difference between the performance ranges of older washing machines and newer machines, although loss of performance with a reduction of the detergent dose from 100% to 50% is much greater than from 150% to 100%. This difference can result from the fact that with the older washing machines it is normally not possible to prevent a loss of detergent in the pump sump. Therefore, considerable proportions of the detergent probably remain unused.

A comparison of the washing performance for the 40°, 60° and 90°C programmes with the corresponding energy consumption (Figure 80) shows surprising results. The distribution of the curves is even less uniform, and it is clear that older washing machines consume require more energy to achieve a good washing performance. Indeed, in order to match the washing performance of new machines in a 40°C programme, old machines have to be operated with the

[87] Shaded areas represent classes of performance in accordance with the EU-Energy label. The washing performance of machines with reduced or increased detergent doses at 40° and 90°C are obtained by linear extrapolation.

90°C programme. The washing performance of old machines at 40°C (the point at the left in the diagram) is much lower than that of newer washing machines.

Figure 80 Washing performance against energy consumption for all machines (coded for year of production)[88]



Source: Our presentation

Taking Class A as the required performance, it is possible to assess the efficiency of a washing machine in terms of the amount of energy needed to achieve this level of performance. Washing performance Class A is the minimum eco-design requirement for domestic washing machines marketed in the European Union ((EU) No. 1015/2010). Although some linear extrapolations have to be made for older machines, it is possible in this way to compare the efficiency of various washing machines over time (Figure 81). As anticipated, the distribution of the values for efficiency is rather irregular, but the general trend is that older machines have a much higher energy consumption than the newer machines for the same washing performance. The trend line shows a much greater level of improvements than would be expected solely on the basis of constant washing temperature, which is attributable to the improved to the improved washing performance of newer washing machines. The investigations from 2004 show that a new machine was using only about half the energy consumed by a 15-year-old machine and a quarter of the energy consumed by a 30-year-old machine in order to achieve the same washing performance. A comparison of water consumption with a constant load shows similar improvements over time.

The explanation for these results lies in the differing lengths of the innovation cycles for washing machines, detergents, and textiles. Until 1991, the 90°C washing programme was the comparison programme used by Stiftung Warentest to assess washing performance. Then

[88] From left to right, consumption at 40°, 60° and 90°C, washing performance is given as an index (corresponding to Classes A to G of the European energy labelling directive). Lines are included for visualisation.

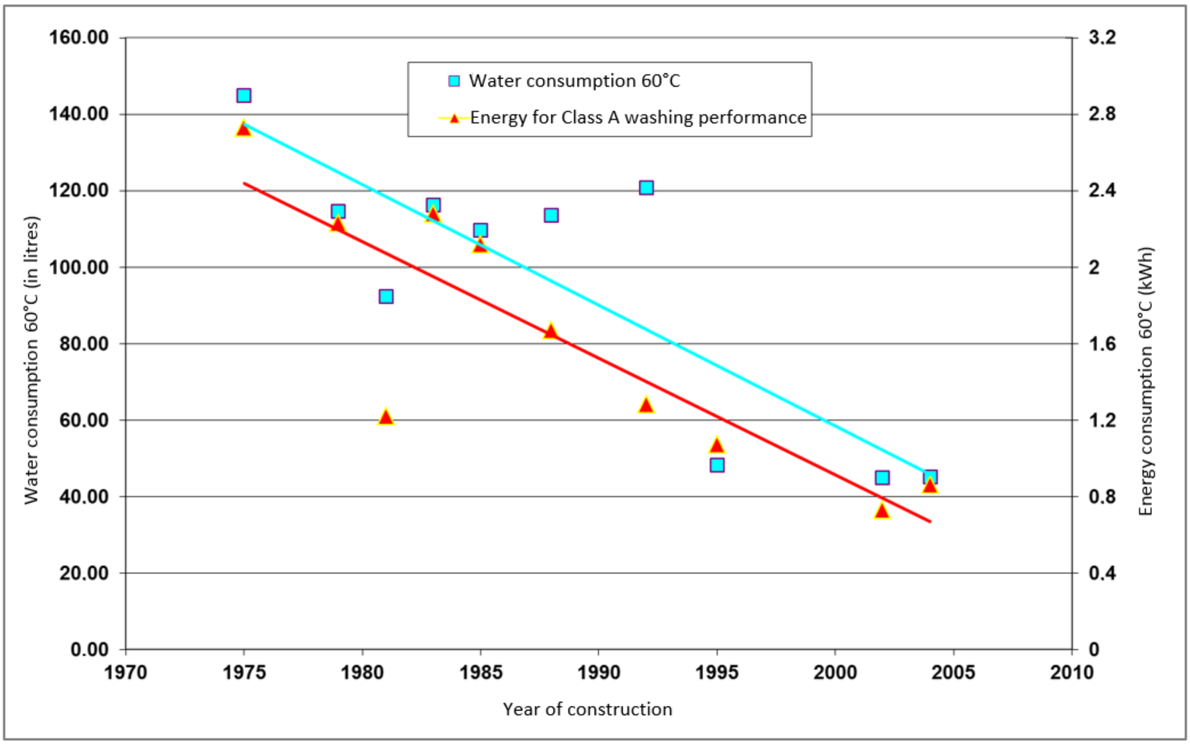
through until 2002, the 60°C coloured wash programme was used for the tests and only afterwards was the 40°C programme used as the test programme. It had been necessary to wash at higher temperatures in order to achieve good results. Only with the introduction of bleach activators in detergents and increasingly efficient enzymes was it possible to lower the washing temperature and still achieve excellent washing results. Other detergent components were also further optimised for use at lower temperatures. However, the washing times at lower temperatures had to be extended. But the older washing machines had only a relatively short washing programmes at lower temperatures because they were intended to be used mainly for only lightly soiled textiles.

Textiles have also undergone further developments over time. In the past, washable textiles consisted mainly of cotton and polyester fibres, but since then a range of other chemical and natural fibres have become available. Modern washing machines offer special programmes for these new textiles.

Older washing machines may therefore still be functional, but only have a limited capability to use modern detergents efficiently and to provide optimum care for modern textiles. In future there will be further developments of washing machines, textiles and detergents, so that in one or two decades today's washing machines will no longer be able to operate satisfactorily with these new detergents and materials.

From the Internet survey (Section **Fehler! Verweisquelle konnte nicht gefunden werden.**, **Fehler! Verweisquelle konnte nicht gefunden werden.**) it can be concluded that such functional obsolescence was the reason for approx. 12% of households to get a new washing machine (combined responses to "The washing machine was not energy-efficient enough." and "The washing machine didn't have enough functions.").

Figure 81 Water consumption and calculated energy consumption to achieve Class A washing performance, according to year of construction



Source: Our presentation

6.7.3 Psychological obsolescence

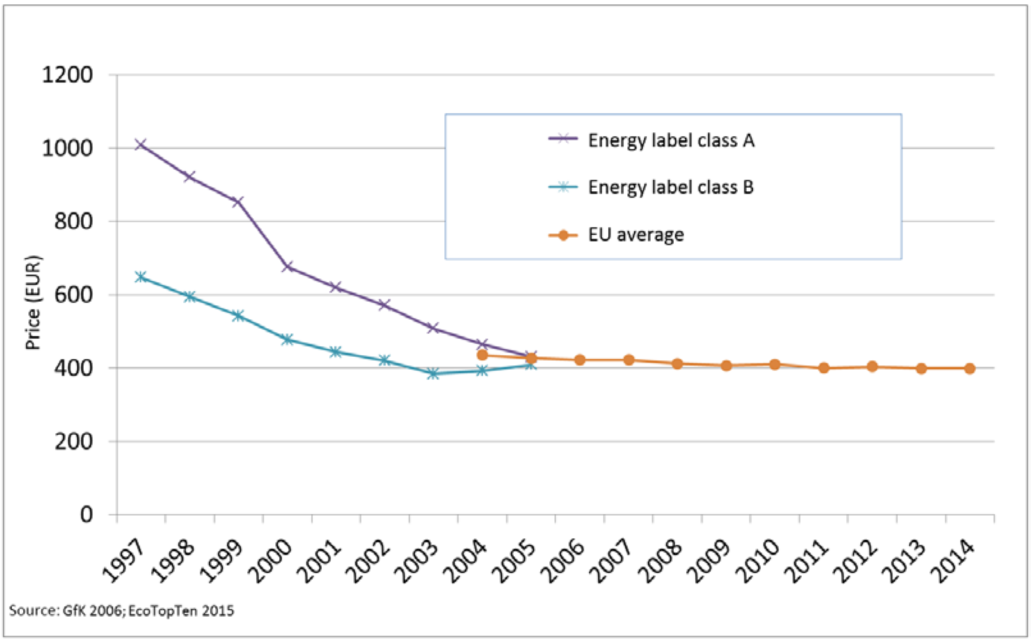
The Internet survey gave as a directly measurable quantity that only 1.2% of the purchases were made because of the wish for a new washing machine ("I didn't like the washing machine any more"). However, it can be assumed that the real proportion is considerably higher. According to the GfK-survey in 2012/2013 (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**), 13.2% of the respondents said that they had bought a new washing machine because "the old machine still worked but I/we wanted a better one". Some of these purchases were made for reasons of psychological obsolescence; most of the rest were probably made for reasons of functional obsolescence. However, using the available data it is not possible to draw more precise conclusions about the importance of psychological obsolescence in the case of washing machines.

6.7.4 Economic obsolescence

The responses received from manufacturers about the likelihood of failure of washing machines components conforms with the results of the duration tests of Stiftung Warentest and the WRAP Study (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**): Practically all parts of a washing machine can fail, with the suds pumps failing more frequently according to the manufacturer responses in in **Fehler! Verweisquelle konnte nicht gefunden werden.**. A repair of this part is possible, but the cost is relatively high (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). This is particularly the case if the repair is carried out in the home, so that travel costs are incurred. On the other hand, repairs by non-specialists are not to be recommended, because washing machines and other electrical household appliances can represent dangerous domestic hazards. Specialists check the electrical safety after completing repairs and confirm this with their signature.

At the same time, there has been a drastic reduction in the prices of new washing machines (see Figure 82) in particular up to 2004. This is probably a consequence of globalisation (overcapacity due to new competitors) and the introduction of the euro (comparability of prices in different countries). In many cases, it is therefore no longer economically viable for consumers to pay for repairs when for much the same money they can buy a new washing machine.

Figure 82 Development of average prices of washing machines in Europe (prices before 2005 for the eight largest markets in the EU)



Source: Our presentation

Consumers choosing to buy a new appliance to avoid repairing an old one can explain the overall reduction in the lifespan and period of use of washing machines (and other large domestic appliances) shown by the comparison of the data of the GfK for the years 2004 and 2012/2013 and the analysis of disposed machines (see Section **Fehler! Verweisquelle konnte nicht gefunden werden.**). (Since the purchase prices of the machines that were disposed of in 2004 had been considerably higher, they were more likely to be repaired).

Table 58 Likelihood of failure according to washing machine manufacturers

Part/component (multiple responses from different manufacturers)	Likelihood of failure			
	Very rare	Rare	Frequent	Very frequent
Inlet/outlet hose	X	X		
Suds pump (pump motor)		X	X	
Pump casing	X			
Springs	X			
Shock absorbers		X		
Bearings	X			
Seals		X		
Suds container		X		
Interference suppression	X			
Pressure sensor		X		

Part/component (multiple responses from different manufacturers)	Likelihood of failure			
	Very rare	Rare	Frequent	Very frequent
Heating		X		
Thermostat		X		
Control electronics (Platine)	X	X		
Input / output electronics (buttons, display)	X	X		
Programme switch/Microswitch		X		
Tacho-generator	X	X		
Door lock (electronics)		X		
Door handle, catch (mechanical)	X	X		
Temperature sensor		X		
Motor (carbon pins)	X			
Aqua Stop system	X			

Table 59 Repair costs according to manufacturers (net prices)

Part /Component	Labour costs (€)	Cost of parts (€)	Time for repair
Inlet/outlet hose	ca. 103	ca. 60 / 23	ca. 30 min.
Suds pump (pump motor)	ca. 125	ca. 53	ca. 45 min.
Pump casing	ca. 125	ca. 16	ca. 45 min.
Springs	ca. 103	ca. 9	ca. 30 min.
Shock absorbers	ca. 146	ca. 30	ca. 60 min.
Bearings	ca. 233	ca. 29	ca. 120 min.
Seals	ca. 125	ca. 20	ca. 45 min.
Suds container	ca. 233	ca. 40 plus 170	ca. 120 min.
Interference suppression	ca. 103	ca. 17	ca. 30 min.
Pressure sensor	ca. 103	ca. 33	ca. 30 min.
Heating	ca. 103	ca. 46	ca. 30 min.
Thermostat	ca. 103	ca. 27	ca. 30 min.
Control electronics (Platine)	ca. 125	ca. 158	ca. 45 min.
Input / output electronics (buttons, display)	ca. 125	ca. 147	ca. 45 min.
Programme switch/Microswitch	-	-	-
Tacho-generator	ca. 125	ca. 23	ca. 45 min.
Door lock (electronics)	ca. 125	ca. 45	ca. 45 min.

Part /Component	Labour costs (€)	Cost of parts (€)	Time for repair
Door handle, catch (mechanical)	ca. 103	ca. 47	ca. 30 min.
Temperature sensor	ca. 103	ca. 46	ca. 30 min.
Motor (carbon pins)	ca. 125	ca. 262	ca. 45 min.
Aqua stop system	ca. 125	ca. 11	ca. 45 min.

6.8 Causal analysis – Small household appliances

6.8.1 Hand mixer and electric kettle

6.8.1.1 Analysis of discarded hand mixers and electric kettles

In a project on the technology and sustainability of food-processing appliances, students at the University of Bonn collected discarded hand mixers and electric kettles from local waste collection points and then attempted to identify the reasons why they had been disposed of.

Conditions

In all, 23 hand mixers and 28 electric kettles were collected from the RSAG-disposal plant Troisdorf in late 2013/early 2014 and investigated in the laboratories of the household technology section of the University of Bonn. It was only possible to identify the date of manufacture of two appliances: one hand mixer was made in June 2004 and a kettle was made in November 2011.

65% of the hand mixers were branded products (= Krups, Philips, Tefal, Moulinex, Bosch, Severin, and Siemens), compared with only 43% of the electric kettles.

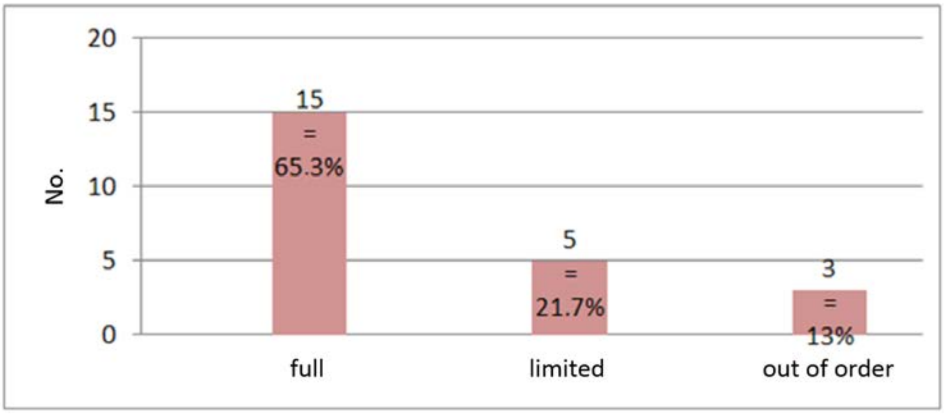
Working order

63% of the discarded hand mixers and 71% of discarded electric kettles showed no obvious faults impairing their use or function, and were classed as “full” working order (Figure 83 and Figure 84).

“Limited” working order (hand mixers: 22%, kettle: 11%) included all appliances that could still be used, but where the use was limited by some technical or mechanical defect. For example, in the case of hand mixers one of the speeds might no longer be usable, or for electric kettles the switch might have to be held down or released manually when the water boiled.

A total of 13% of hand mixers and 11% of the kettles were out of order, and could no longer be used for the intended function of the appliance.

Figure 83 Working order test – Hand mixers



Source: Our presentation

Figure 84 Working order test – Electric kettles

Source: Our presentation

External appearance and design

The external inspection showed that two of the hand mixers were impaired. In one case the casing was cracked, and in another the cable insulation was broken. However, both appliances were otherwise in full working order.

Five out of 28 electric kettles showed external defects. It was only possible to determine with certainty that this damage did not originate from rough handling in the recycling centre or waste collection point for two of the appliances. In these cases, a break had been taped up by the user at some time.

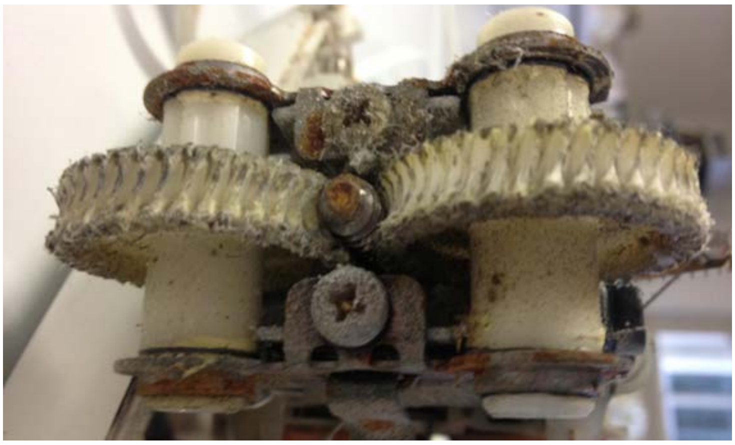
A hand mixer and an electric kettle were very outdated, with very angular design and discolorations. All other appliances had a neutral or modern design. For example, the modern appliances characteristically had chrome finishes.

Internal inspection

After testing their functioning and assessing the external appearance, the hand mixers were dismantled and the interior of the kettles was inspected visually.

For the hand mixers, in particular the cog teeth and the carbon brushes of the motors were examined. In none of the appliances were the carbon brushes so worn that this would have been the reason for the failure of the appliance. The cog wheels showed heavy wear in 43.5% of the appliances, but this wear had only led to complete or partial loss of function in 34.8% of these appliances (Figure 85).

Figure 85 Example of worn cog-wheels of a hand mixer



Source: Our photograph

The inspection of the electric kettles showed that 39% (n=11) were heavily scaled (Figure 86). However, 82% of these were still fully functional. It can be concluded that the scaling was a possible reason for the consumer to dispose of the appliance, although this had not put the appliance out of working order.

Figure 86 Scaling in a kettle

Source: Our photograph

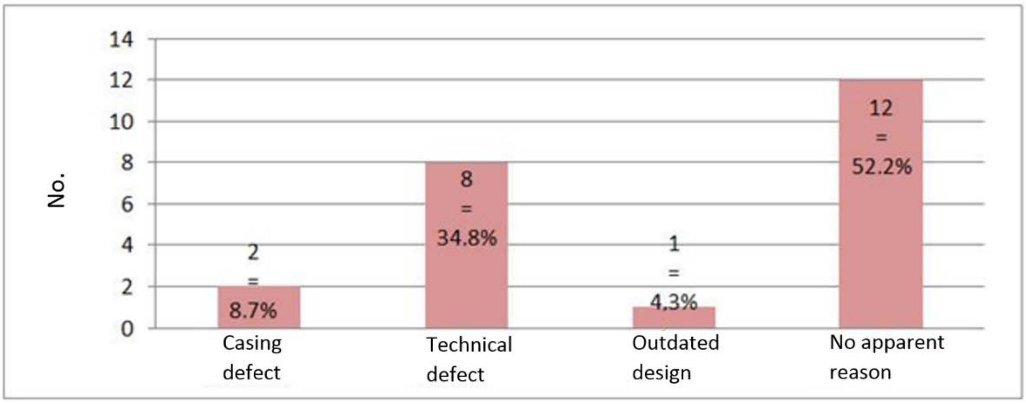
Indications of earlier repairs

None of the hand mixers showed internal signs of previous repairs. Only one of the electric kettles showed signs of having been repaired, with one of the four fixing screws out of alignment.

Probable reasons for disposal

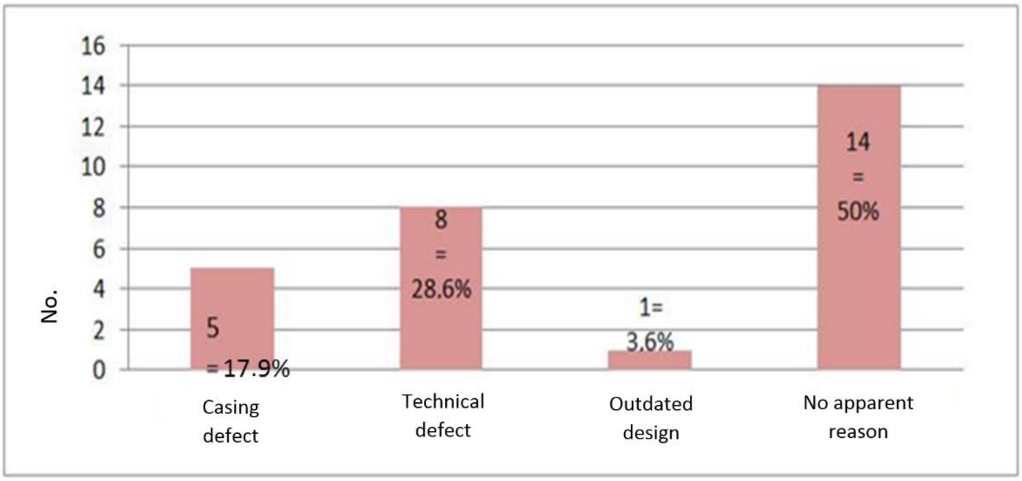
Finally, the probable reason for disposal was determined. Regarding the hand mixers (Figure 87), in 52% of the cases the reason for disposal was not apparent, and it was not possible to establish any technical or mechanical defects or design related causes. For 9% of the hand mixers, the probable reason for disposal was a defective casing, and 35% of the appliances had a technical fault which was likely to have been the reason. In these cases, the cog wheel was so worn that the whisks or beaters would not rotate properly, or not at all.

Figure 87 Probable reason for disposal - hand mixers



Source: Our presentation

Figure 88 Probable reason for disposal - electric kettles



Source: Our presentation

For 50% of the electric kettles there was no apparent reason for disposal (Figure 88), and it was not possible to establish any technical or mechanical defects or design related causes. However, 64% of these appliances were heavily scaled, which could indicate that the appliances had been disposed of because of scale build up. For 17.9% of the appliances, a casing defect was the probable reason for disposal. And 28.6% of the electric kettles were probably disposed of because a technical defect impaired the functioning.

Since none of the hand mixers and only one electric kettle showed signs of previous repairs, it can be assumed that consumers disposed of appliances rather than attempting to have them repaired.

No connections were found between the reason for disposal and the nature of the product (branded/non-branded).

Overall, the tests indicate that a functional failure was only the reason for the disposal of hand mixers and electric kettles in a few cases. In 50% of cases in our tests the users terminated the working life of the appliance without being forced to dispose of it due to a loss of function.

6.8.1.2 Results of the internet-based consumer survey – hand mixers

Hand mixers purchased new or second-hand

Hand mixers were mostly bought new (89 %), and only rarely second-hand (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 60 New or second-hand hand mixer

Was the hand mixer bought new or second-hand?	Frequency	%
New	441	89.1
Second-hand	50	10.1
I don't know.	4	0.8
Total	495	100.0

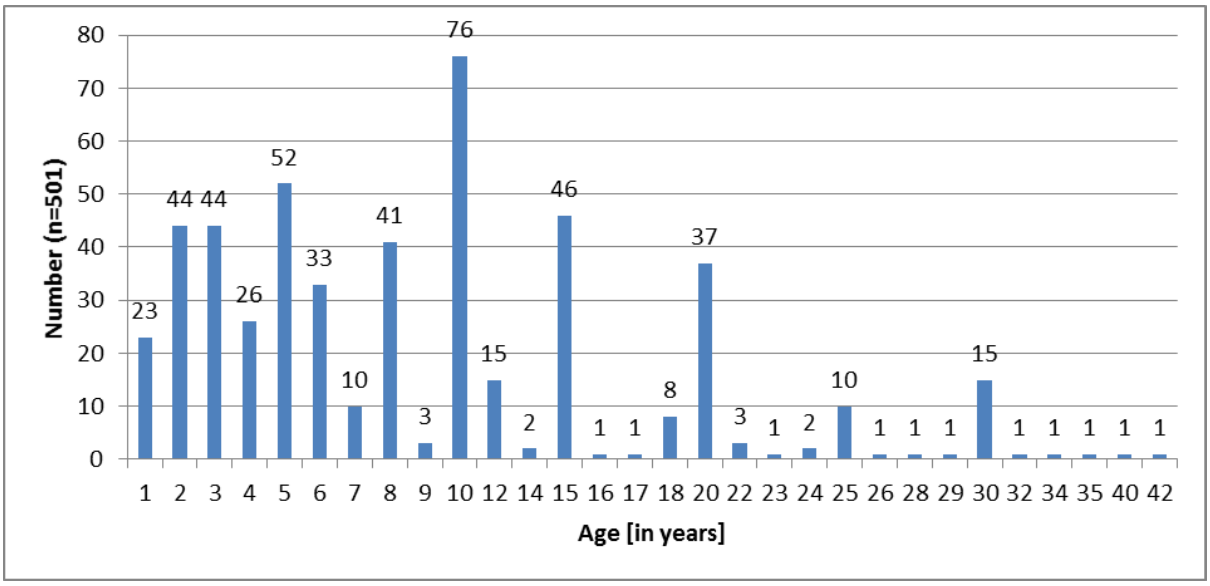
Age of the hand mixer

On average, hand mixers were reported to be 10 years old at disposal (**Fehler! Verweisquelle konnte nicht gefunden werden.**), but once again the choice of round numbers suggests memory bias (Figure 89).

Table 61 Lifespan distribution of the hand mixers

How old was the hand mixer at the end? If you do not know, please estimate a value [in years].								
N	Mean	SD	Min	Max	25th percentile	Median	75th percentile	Range
501	9.8	7.6	1	42	4	8	15	41

Figure 89 Age of the hand mixer



Source: Our presentation

Price of hand mixers

Most of the hand mixers were medium-priced appliances, followed by inexpensive appliances (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 62 Price of the hand mixer

How expensive was this hand mixer?	Frequency	%
An inexpensive appliance (no name)	144	28.8
A medium-priced appliance	200	40.0
An expensive appliance (top brand)	97	19.4
I don’t know.	59	11.8
Total	500	100.0

Repair of the hand mixer

94 % of the hand mixers had never been repaired (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Only three out of 23 repairs were carried out under warranty (

).

Table 63 Repair of the hand mixer

Has this hand mixer ever been repaired?	Frequency	%
Yes	25	5.0
No	468	93.6
I don’t know.	7	1.4
Total	500	100.0

Table 64 Repair under warranty hand mixer

Was the repair carried out in the warranty period?	Frequency	%
The repair was carried out in the warranty period.	3	13.0
The repair was carried out after the warranty had expired.	16	69.6
I don’t know if the repair was carried out in the warranty period.	4	17.4
Total	23	100.0

Frequency of use of the hand mixer

Hand mixers are rarely used every day, and the majority are used between once a week and once a month (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 65 Use of the hand mixer

How often have you used this hand mixer as a rule? If you do not know, please estimate a value.	Frequency	%
Almost never	27	5.4
Once a month	149	29.6
Once a week	209	41.6
Several times a week	113	22.5
Daily	5	1.0
Total	503	100.0

Fate of the hand mixer

85 % of the hand mixers had been disposed of, with a relatively small proportion passed on or stored away (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 66 Fate of the hand mixer

What did you do with the old appliance?	Frequency	%
Disposal	427	85.2
Passed it on (sold, given away)	39	7.8
Stored away	31	6.2
Some other option	4	0.8
Total	501	100.0

Reason for getting a new hand mixer

In most cases (76.2%), interviewees said that they had replaced their old hand mixer because it was broken. It is interesting to compare this with the results of the investigation of appliances retrieved from the waste collection points (cf. Figure 87), which found that 9% of the hand mixers seemed to have been disposed of because of a defective casing and 35% because of a technical defect. This is a very different picture. Possibly, many hand mixers are disposed of because the consumers think that they are broken although they are still in working order.

Relatively few participants said that they no longer liked the hand mixer or that it did not have enough functions, and 8% said they had some other reason (**Fehler! Verweisquelle konnte nicht gefunden werden.**). More hand mixers are disposed of than are defective (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 67 Reason for buying a new hand mixer

Why did you get rid of the hand mixer? Choose the most appropriate reason.	Frequency	%
The hand mixer was broken	381	76.2
I didn’t like the hand mixer any more	32	6.4

Why did you get rid of the hand mixer? Choose the most appropriate reason.	Frequency	%
The hand mixer did not have enough functions	13	2.6
I was given a new hand mixer	34	6.8
I had another reason	40	8.0
Total	500	100.0

Satisfaction with the lifespan of the hand mixer

34 % of the participants were dissatisfied with the lifespan of their hand mixer. 60 % were satisfied (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 68 Satisfaction with the lifespan of the hand mixer

How satisfied were you with the lifespan of the dieses hand mixer?	Frequency	%
The lifespan met my expectations	182	36,3
I was surprised how long the hand mixer lasted	69	13.8
It was time to replace the hand mixer with a new one	51	10.2
I had expected it to last longer	104	20.8
The hand mixer only worked for much too short a time.	67	13.4
I don't know	28	5.6
Total	501	100.0

Defect of the hand mixer

The defects of the hand mixers were mostly related to the electrics or the mixing attachments (together 66 %). 17 % were due to some other unnamed defect, while 19 % of participants said that they did not know the reason (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 69 Defect of the hand mixers

What exactly was wrong with the hand mixer?	Frequency	%
Cable breakage	11	2.9
Switch	13	3.4
Settings	20	5.2
Whisk attachment	106	27.7
Electrical fault	145	37.9
Something else	66	17.2
I don't know	71	18.5
Total no. of responses	432	112.8
Total no. of participants	383	100.0

6.8.1.3 Test reports: Hand mixers, hand blenders, compact food processors and juicers

The test procedures used by Stiftung Warentest for small electrical appliances consists of:

- Hand mixer: 150 cycles whisking, 360 cycles kneading,
- Hand blender: 450 cycles, with 150 mix-phases in water and 300x blending,
- Compact food processors: 500 cycles (300x with oil-sawdust mix, 100x with moulding dough, 100x unloaded)
- Juicers: 500 cycles (@ 10 x 2 minutes with 1-minute break, then 1 hour cooling).

The small kitchen appliances can be grouped together because they fail for similar reasons. These appliances, used mostly to process foodstuffs, fail mainly when the motor is overloaded (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Some manufacturers give a maximum operating period, after which a pause should be made. But if in the case of a hand blender a maximum of 15 seconds is given, then clearly such brief periods of use are clearly unrealistic.

A critical point for hand mixers with a rotating bowl is the drive chain. If this is worn, then at best it is still possible to use only the hand mixer without having to dispose of the entire appliance.

Table 70 Duration testing of small kitchen appliances by Stiftung Warentest

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2012/03	24	Hand mixer	Grundig HM 5040	Cause unknown
			Dualit HMR 1	Cause unknown
			bodum Bistro	Cause unknown
2012/03	24	Hand mixer with rotating bowl	Philips HR 1565	Bowl drive worn out, mixer OK
			Severin HM 3814	Bowl drive worn out, whisks come loose, mixer OK
			Bosch MFQ 3560	Bowl drive worn out, mixer failed
			efbe-Schott RG 310	Bowl drive worn out, mixer failed
2003/01	12	Hand mixer	CTC Clatronic HM 2642	Cause unknown
2011/08	22	Hand blender (+fittings)	Bosch Styline MSM 7800	Turbo-taste gives out, hand blender still works
			Philip HR1377	Motor failure
			Red Baron SM 5006	Cause unknown
			Tefal Click&Mix 450	Motor failure
			Severin Profi Mix 3807	Motor failure very early
2011/08	22	Hand blender	Real/Alaska STM1200	Motor failure

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2003/01	12	Hand blender	Solac INOX 400	Motor failure very early
			Severin SM 9617	Motor failure very early
			Superior HM 932A-2	Motor failure very early,
			Moulinex Spiralio A DG1 42	Cause unknown
			Philips Cucina HR 1350/6	Cause unknown
			CTC Clatronic SM 2680	Cause unknown
1996/10	20	Kompaktfood processors	Philips Compacto HR 2830	Cause unknown, early failure
			CTC Clatronic KM E 2172	Cause unknown, early failure
2013/08	15	Juicer	Severin ES 3559	Motor damage
			Clatronic AE 3465	Motor damage
			Tristar SC-2283	Motor damage
			Petra Electric Vitapure	Motor damage
2003/07	14	Juicer	Braun Multipress MP80	Wear of motor mounting
			Suco Saftpresse	Crack of the grater, early failure
			CTC Clatronic AE 2758	Early failure
			Kenwood JE550	Early failure
			Philips Cucina HR 2828/26	Early failure
			Severin Juice 300 ES3556	Early failure
			Unold Electro Saftcenter 8850	Early failure

6.8.1.4 Results of the internet-based consumer survey – electric kettles

Responses are included from the 692 participants of the consumer survey about the electric kettle they had most recently.

New or second-hand electric kettle

Electric kettles are mostly bought new. Only in 7 % of cases was a second-hand kettle purchased (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 71 Electric kettles purchased new or second-hand

Was the kettle bought new or second-hand?	Frequency	%
New	633	91.9
Second-hand	45	6.5
I don't know	11	1.6
Total	689	100.0

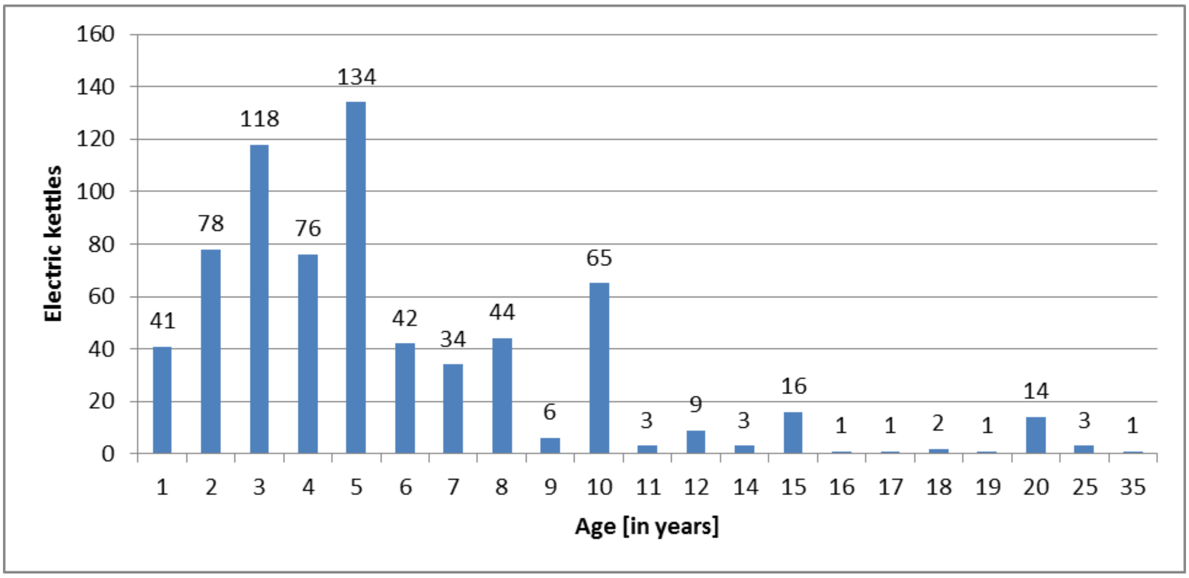
Age of the electric kettle

The kettles replaced by the participants of the consumer survey were on average 5.7 years old (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). Once again, there are notable clusters at "round" numbers (see Figure 90).

Table 72 Lifespan distribution of the kettle

How old was the kettle? If you do not know, please estimate a value [in years].								
N	Mean	SD.	Min.	Max	25th percentile	Median	75th percentile	Range
692	5.7	4.2	1	35	3	5	7	34

Figure 90 Age of the electric kettle



Source: Our presentation

Price of the electric kettle

More than half the electric kettles were inexpensive appliances. Only 8% were expensive kettles (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 73 Price of the electric kettle

How expensive was the electric kettle?	Frequency	%
An inexpensive appliance (no name)	348	50.4
A medium-priced appliance	233	33.7
An expensive appliance (top brand)	56	8.1
I don't know.	54	7.8
Total	691	100.0

Repair of the electric kettle

In fewer than 3 % of cases had the recently replaced kettle been repaired (**Fehler! Verweisquelle konnte nicht gefunden werden.**), and of these only five had been repaired under warranty (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 74 Repair of the electric kettle

Was the electric kettle ever repaired?	Frequency	%
Yes	17	2.5
No	664	96.8
I don't know.	5	0.7
Total	686	100.0

Table 75 Repair under warranty - kettle

Was the repair carried out during the warranty period?	Frequency	%
The repair was carried out in the warranty period.	5	29.4
The repair was carried out after the warranty had expired.	11	64.7
I don't know if the repair was carried out in the warranty period.	1	5.9
Total	17	100.0

Frequency of use of the electric kettle

Electric kettles are usually used daily or several times a day (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 76 Use of the electric kettle

How often did you use this kettle as a rule? If you do not know, please estimate a value.	Frequency	%
Almost never	3	0.4
Once a month	10	1.5
Once a week	53	7.7
Several times a week	177	25.7

How often did you use this kettle as a rule? If you do not know, please estimate a value.	Frequency	%
Daily	241	35.0
Several times a day	204	29.7
Total	688	100,0

Fate of the electric kettle

84 % of the kettles from the Consumer survey were thrown away. In only a few cases was the kettle stored away or passed on (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 77 Fate of the electric kettle

What did you do with the old kettle?	Frequency	%
Disposal	580	84.1
Passed it on (sold, gave it away)	54	7.8
Stored away	43	6.2
Some other option	13	1.9
Total	690	100.0

Reason for buying a new electric kettle

68 % der participants claimed to have replaced their old kettle because of a defect. 13 % said they had some other reason (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). According to the consumer survey, more electric kettles were disposed of than were defective (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**). A comparison with the investigation of kettles collected at the recycling centre is interesting (cf. Figure 88). According to this, 17.9% of the appliances would seem to have been disposed of due to a mechanical defect of the housing, and a technical fault that limited the functionality of 28.6% of the appliances was presumably the reason for their disposal. The consumer survey therefore gives a different impression of the reasons for disposing of electric kettles. It may be that many electric kettles are disposed of because the consumers think they are defective, although in fact the appliance would still work.

Table 78 Reason for buying a new electric kettle

Why did you get rid of the electric kettle? Choose the most appropriate reason.	Frequency	%
The electric kettle was defective.	470	68.0
I didn’t like the electric kettle any more.	64	9.3
The electric kettle didn’t have enough functions.	12	1.7
I was given a new electric kettle.	37	5.4
I had another reason.	91	13.2
The electric kettle was not energy-efficient enough.	17	2.5

Why did you get rid of the electric kettle? Choose the most appropriate reason.	Frequency	%
Total	691	100.0

Satisfaction with the lifespan of the electric kettle

Some 35 % of the participants were not satisfied with the lifespan of the electric kettle, 58 % were satisfied or very satisfied (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 79 Satisfaction with the lifespan of the electric kettle

How satisfied were you with the lifespan of this electric kettle?	Frequency	%
The lifespan met my expectations	248	35.8
I was surprised how long the electric kettle lasted.	52	7.5
It was time to replace the electric kettle with a new one.	116	16.8
I had expected to be able to use it longer.	169	24.4
The electric kettle didn’t last nearly long enough.	81	11.7
I don’t know.	26	3.8
Total	692	100.0

Defect of the electric kettles

28 % der electric kettles were disposed of because of a defective heating element, for a further 19 % the automatic power cut-out was defective (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). 23 % of the participants were not able to give further details of what was wrong.

Table 80 Defect of the electric kettle

What exactly was wrong with the electric kettle?	Frequency	%
Cable fault	19	4.0
Switch	53	11.2
Heating element	133	28.1
Automatic cut-out	91	19.2
Lid or vessel	68	14.4
Something else	78	16.5
I don’t know.	109	23.0
Total no. of responses	551	116.5
Total no. of participants	473	100.0

6.8.2 Electric toothbrushes

The test procedure of Stiftung Warentest for electric toothbrushes consists of 2,250 test cycles (@ 4 x 2 minutes, with 1-minute breaks between cycles), which corresponds to six years of use by two people. Throughout the cycle, a toothpaste-water mix ran over the brush.

The durability of electric toothbrushes was predominantly assessed as “good” or “very good”. Battery toothbrushes generally did worse that rechargeable electric toothbrushes. Declining performance of rechargeable batteries was only rarely reported. No reasons were given if products failed the duration test (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 81 Duration testing of electric toothbrushes by Stiftung Warentest

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2013/04	14	Electric toothbrushes	Grundig sonic toothbrush TB 8030	Cause unknown, early failure
			Incutex Dental Care Electromotive Brush	Cause unknown
2011/05	10		Colgate Sonic Energy (only battery toothbrush in test)	Brush head cannot be exchanged (duration ca. 3 months)
2003/05	10		Dr. BEST Brillant	Cause unknown
			Severin Denti-Care HG 7704	Cause unknown

6.8.3 Espresso machines

The test procedure of Stiftung Warentest for espresso machines consisted of:

- 6 000 cycles: @ 10 x 1 cup with a 15-minute cooling phase between cycles,
- Descaling and cleaning according to manufacturer’s instruction or the display signal,
- Water hardness: ca. 3.6 millimole (21ºdH).

The annual test of espresso machines does not reveal frequent lifespan problems. Both the electronics and the mechanics (grinder) can cause malfunctions (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 82 Duration testing of espresso machines by Stiftung Warentest

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2013/12	4	Espresso machine	Krups EA 8258	Coffee runs out of the sides, internal condensation → Display mists up, machine drips
			De’Longhi ECAM 25.457	Wrong command “insert brew group” (overheating?)

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2012/12	14	Espresso machine	De'Longhi Primadonna S ECAM 26.455	Wrong command "insert brew group" (overheating?)
2010/12	12	Espresso machine	Jura ENA 7	Liable to break down
2008/12	15	Espresso machine	Spidem My Coffee Rapid Steam	Ground coffee blocked inlet to brew group
			Krups Espresseria Automatik EA 8080	Beans block grinder → Electronics fail
2005/12	14	Espresso machine	Saeco Café Crema Silber	Removable brew group failed near the end of the duration test
2004/12	17	Espresso machine	Jura Impressa F50	Grinder failed
			Saeco Incanto Sirius SUP02 YADR	Grinder failed
			Saeco Incanto rondó SUP02 1YO	Grinder failed
1999/12	14	Espresso machines	AEG EA 100 Crema	Cause unknown
1997/09	20	Espresso machines	Eduscho Cafissimo 757371	Metal shavings produced from the water tank thread
			La Pavoni Europiccola Lusso	
1994/09	16	Espresso machines	Braun Espresso Maser E 250 T	For all products, metal shavings produced from the water tank thread
			Ismet ES 561	
			Source Privileg 611.104	
			Severin KA 5950	
			EGS Presto Cappuccino	

6.8.4 Steam irons

Stiftung Warentest tests steam irons under the following conditions:

- Water hardness: approx. 17°dH,
- Descaling according to the user instructions,
- Tests were terminated if the appliance was defective, the rate of steam release was less than 5 g/min., or at the end of the 240-hour test period,
- Scratch resistant soleplate.

The most frequent lifespan problem of steam irons is scaling (**Fehler! Verweisquelle konnte nicht gefunden werden.**). This blocks the steam outlets and can at times cause the heating to fail. Whether leaks in the water pipes in the appliance are attributable to scaling is not apparent from the test results.

Table 83 Duration testing of steam irons by Stiftung Warentest

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2012/12	8+6	Steam irons + ironing stations	Laurastar G7	Water leak (42 hours)
			Severin BA 3210	Scaling, jets blocked (92 hours)
			AEG 5Safety DB 8040	Heating fault (95 hours)
2009/01	16	Steam irons	Severin BA3259	Scaling; soleplate not scratch resistant
			AFK DB-2200.8	Scaling
			Beem Power Generator EV03 Pro-C	Scaling; live parts exposed after drop test; soleplate not scratch resistant
2000/08	19	Steam irons	Alaska DB 1310	Scaling
			Source Privileg Best.Nr. 4881949	Scaling
			Severin BA 3255	Scaling
1996/08	18	Steam irons	Moulinex AL 9	Cause unknown
			Tefal Turbogliss 2500	Cause unknown

6.8.5 Vacuum cleaners

The test procedure of Stiftung Warentest for vacuum cleaners consists of:

- Motor duration testing: 600 hours, without interruptions,
- Bump test (500 cycles): The vacuum cleaner crosses 10 000 times over a threshold and bumps 1 000x against a doorpost,
- Drop test: The suction head is dropped 1 200 times from a height of 80 centimetres,
- Testing cable drum: The cable is drawn out and rewound 6 000 times,
- Test of hose connections: swung 40 000x from connected hose,
- Compression of pipes, hose and side ventilation: the tester applies 70 kg load for 10 seconds

The evaluation of vacuum cleaner tests over the past 20 years regularly shows the failure of the motor due to premature wear of the carbon brushes (**Fehler! Verweisquelle konnte nicht gefunden werden.**). In most cases, mechanical damage to the housing does not lead to a limitation of the lifespan, but resulted in a poorer result for the duration testing.

Table 84 Duration testing of vacuum cleaners by Stiftung Warentest

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
2014/02	13	Vacuum cleaner	Kalorik TKG VC 1006	Motor failure, housing susceptible to bump damage
2012/12	10	Vacuum cleaner	Hoover Xarion TXG 1210 Green Ray	Spring of cable drum, hose connection broken
2009/04	11	Vacuum cleaner	Panasonic MC-CG881	Motor failure
			Solac Eco Apollo AS 3250	Motor failure
2008/04	15	Vacuum cleaner	LG V-KC902 HTM	Susceptible to bump damage
			Fakir 2100	Susceptible to bump damage, Motor failure
2007/04	19	Vacuum cleaner	Siemens VS06G 1666	Damage to head or housing in bump/drop tests → this damage can be repaired
			Source/Privileg VS06PR32	
			Dirt Devil Antiinfectiv R1M8028	
			AEG/ELux Cyclone XL ACX6203	
			Samsung SC 7253	
			Panasonic MC-CG 467	
2006/04	17	Vacuum cleaner	Panasonic MC-E8024	Motor failure
			Coop/Satrap aspira mouse 1500	Mechanical damage to housing
			Fakir prestige 1800	Motor failure very early
2005/04	15	Vacuum cleaner	LG V-CA404STQ	Motor failure due to defective carbon brushes
			Clatronic BS 1237	Motor failure due to defective carbon brushes
			Otto/Hanseatic Dust master 2000	Faulty front wheels, but still functional
2004/04	13	Vacuum cleaner	Lux TopLux1 S D820	Electric nozzle failed; carbon brushes worn after 335 hours
			Samsung VC-8930E	Carbon brushes worn after 230 hours
2003/04	13	Vacuum cleaner	Panasonic MC-E 886	Cause unknown
2002/04	13	Vacuum cleaner	AEG T2	Defects to motor, electronics and telescopic hose
2001/08	8		Rainbow E-1	Roller ball defective

Published (yyyy/mm)	No. of models in test	Type of appliance	Name of appliance	Lifespan problem
		Special vacuum cleaner	Polti L´Ecologico compact AS 800	Roller ball defective and motor failed after ca. 300 hours
			Hitachi CV 2800	Motor failed after ca. 350 hours
1999/04	2	Bagless vacuum cleaner	Dyson dual cyclone DC 03	Motor failed in last third of test
1998/04	14	Vacuum cleaner	Panasonic MC-E962 with Electrojet	Motor if electric nozzle failed (carbon brushes worn out very early)
			Hoover Micro Power Electronic SC 150	Motor failed early
			Rowenta dymbo RS 014	Motor failed early

7 Ecologic and economic comparative analyses between short-life and long-life products

For three selected product groups (washing machines, television and laptops), a short-life and a long-life product was selected in each case for Life Cycle Assessment (LCA) on the basis of EN ISO 14040/14044) as well as for Life Cycle Costing (LCC) on the basis of UNEP/SETAC 2011[89].

7.1 Ecologic comparative analysis

7.1.1 Methodological approach

The entire life-cycle of a product was assessed (resource extraction, manufacture, processing and transport, use, re-use and disposal). The impact was assessed using the following methods and indicators.

Table 85 Methods and parameters used in the assessment

Method	Parameters considered in the assessment	Source and comments
Cumulative energy demand (CED)	CED $_{non\text{-}regenerative}$	ecoinvent, see ecoinvent report No. 3 (2010), pp. 33-40.
IPCC 2007	GWP_{100a} (Global warming potential)	IPCC 2007, see also ecoinvent report No. 3 (2010), pp. 136-142.
ReCiPe Midpoint (H) w/o LT	Terrestrial acidification w/o LT, TAP 100 w/o LT (Acidification potential)	LCIA method, results at mid-point level, (H = Human), see also Goedkoop et al. (2009) and ecoinvent report No. 3 (2010), pp. 143-148.
	Marine eutrophication potential w/o LT; MEP w/o LT	
	Freshwater eutrophication W/O LT, FEP w/o LT	
	Photochemical oxidant formation w/o LT POFP w/o LT	
	Water depletion w/o LT, WDP w/o LT	
	Agricultural land occupation (ALOP) m^2a	

These impact indicators are implemented in the life-cycle assessment software Umberto NXT. As shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, parameters were used for three assessment methods. Data was drawn from the ecoinvent 3.01 database. The individual categories are defined in Annex III.

In addition, the future development of power generation in Germany was also taken into consideration. Use was made of the German Environment Ministry study for 2011[90] on the development of German gross power generation from 2010 in five-year steps until 2020 and in a 10-year step until 2030 (GEM study). The power station types used in the study were allocated

[89] UNEP / SETAC (2011): Towards a Life Cycle Sustainability Assessment – Making informed choices on products, UNEP / SETAC Life Cycle Initiative, http://www.unep.org/pdf/UNEP_LifecycleInit_Dec_FINAL.pdf

[90] BMUB (2012): *Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global*, BMU - FKZ 03MAP146, 29 March 2012; http://www.fvee.de/fileadmin/publikationen/Politische_Papiere_anderer/12.03.29.BMU_Leitstudie2011/BMU_Leitstudie2011.pdf

to corresponding types in the ecoinvent 3.01 database, which required some generalisations and simplifications (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Table 86 Allocation table for the future development of electricity supplies in Germany

Power generation from…	In Umberto modelled as…	Comment
Coal / other solid fuels	electricity production, hard coal [DE] + treatment of municipal solid waste, incineration [DE]	For coal and other solid fuels (waste) the proportion of the ecoinvent-mix was calculated as 18.5% coal + 1.4% waste. An annual conversion factor was calculated as follows: % in GEM study / % in ecoinvent = Conversion factor. All gas inputs were multiplied by this factor.
Lignite	electricity production, lignite [DE]	The proportion of lignite was determined in accordance with the GEM study by means of a specific annual factor. Since only a supply process is involved, the corresponding share of the mix can be adjusted directly.
Natural gas / Oil / Other gases	treatment of blast furnace gas, in power plant [DE] + electricity production, oil [DE] + electricity production, natural gas, at conventional power plant [DE] + electricity production, natural gas, 10MW [DE] + treatment of coal gas, in power plant [DE]	The proportion of the various gases and oil in the ecoinvent mix was determined (14.3%). An annual conversion factor was calculated as follows: % in GEM study / % in ecoinvent = Conversion factor. All inputs were multiplied by this factor.
Nuclear power	electricity production, nuclear, pressure water reactor [DE] + electricity production, nuclear, boiling water reactor [DE]	The proportion of nuclear power in the ecoinvent mix was determined. An annual conversion factor was calculated as follows: % in GEM study /% in ecoinvent = Conversion factor.
Hydroelectricity	electricity production, hydro, run-of-river [DE] + electricity production, hydro, reservoir, non-alpine region [DE] + electricity production, hydro, pumped storage [DE]	The proportion of the various hydroelectric sources in the Ecoinvent Mix was determined. An annual conversion factor was calculated as follows: % in GEM study /% in ecoinvent = Conversion factor.
Wind (onshore)	electricity production, wind, 1-3 MW turbine, onshore [DE] + electricity production, wind, >3 MW turbine, onshore [DE] + electricity production, wind, < 1MW turbine, onshore [DE]	The proportion of onshore wind power in the ecoinvent-mix was determined. An annual conversion factor was calculated as follows: % in GEM study / % in ecoinvent = Conversion factor.
Wind (offshore)	electricity production, wind, 1-3 MW turbine, offshore [DE]	The proportion of offshore wind power generation was determined in accordance with the GEM study by means of a specific annual factor. Since only a supply process is involved, the corresponding share of the mix can be adjusted directly.

Power generation from...	In Umberto modelled as...	Comment
Photovoltaics	electricity production, photovoltaic, 3 kWp slanted-roof installation, multi-Si, panel, mounted [DE] + electricity production, photovoltaic, 570 kWp open ground installation, multi-Si [DE] + electricity production, photovoltaic, 3 kWp slanted-roof installation, single-Si, panel, mounted [DE]	For the modelling, the total proportion of photovoltaic electricity is divided equally between the three ecoinvent-datasets.
Biomass, total	heat and power co-generation, wood chips, 6400 kW thermal, with extensive emission control [DE] + heat and power co-generation, biogas, gas engine [DE] + electricity production, geothermal [DE]	Firstly, the proportion of electricity from biomass use in the ecoinvent-mix was determined. An annual conversion factor was calculated as follows: % in GEM study/% in ecoinvent = Conversion factor.
Imported power	electricity, high voltage, import from DK [DE] + electricity, high voltage, import from PL [DE] + electricity, high voltage, import from FR [DE] + electricity, high voltage, import from NL [DE] + electricity, high voltage, import from AT [DE] + electricity, high voltage, import from CZ [DE]	The origins of the imported power share could not be specified. They were used without introducing a multiplication factor .
Infrastructure costs, distribution and conversion losses	market for electricity, high voltage [DE] + market for transmission network, electricity, high voltage [GLO] + market for transmission network, long-distance [GLO] + electricity voltage transformation from high to medium voltage [DE] + market for electricity, medium voltage [DE] + natural gas, burned in gas turbine, for compressor station [DE] + market for transmission network, electricity, medium voltage [GLO] + market for sulphur hexafluoride, liquid [GLO] + electricity voltage transformation from medium to low voltage [DE] + market for distribution network, electricity, low voltage [GLO] + market for electricity, low voltage [DE]	For this dataset the standard settings/specifications in the ecoinvent dataset were not changed.

As an additional simplification, it was assumed that for the period until 2030 only the composition of the power generation would change, while the specific efficiencies and emissions factors for each type of power generation remains the same. For the period from 2011 to 2030, interpolation was used between the values presented in the GEM study.

Potential environmental impacts relating to the power consumption of an appliance are based on the product of the annual power consumption multiplied by the specific power mix for that year.

The environmental costs for power generation in the use phases of the appliances are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**:

Table 87 Environmental costs for the provision of electricity in accordance with the predicted development of the German electricity mix in the BMUB study 2011 (BMUB 2012); with reference to 1 kWh electricity, low voltage

Category	Unit	Electricity mix Germany					
		2011	2014	2017	2020	2030	2050
CED_{fossil}	MJ	8.12	8.31	7.36	6.54	5.62	4.55
$CED_{nuclear}$	MJ	2.94	2.51	2.17	1.90	0.53	1.24
$CED_{non\text{-}regenerative}$	MJ	11.06	10.82	9.53	8.44	6.15	5.79
GWP_{100a}	kg CO_2-eq	0.69	0.69	0.61	0.53	0.43	0.37
WDP	m^3	0.01	0.01	0.01	0.01	0.01	0.01
TAP_{100}	kg SO_2-eq	1.07E-03	1.12E-03	1.07E-03	1.02E-03	1.01E-03	9.96E-04
FEP	kg P-eq	7.89E-04	7.54E-04	6.49E-04	5.16E-04	3.15E-04	3.11E-04
MEP	kg N-eq	2.66E-04	2.76E-04	2.64E-04	2.44E-04	2.26E-04	2.59E-04
POFP	kg NMVOC	7.83E-04	8.22E-04	7.71E-04	7.32E-04	7.34E-04	6.78E-04
ALOP	m^2a	0.04	0.04	0.05	0.05	0.06	0.08

7.1.2 Washing machines

The functional unit is a washing machine as typically used in private households. The reference year for the purchase of the washing machines was 2011. The investigation covered a period of 20 years, i.e. until 2031.

Manufacture and distribution are considered globally, with use in Germany. This applies in particular for modelling the provision of electricity in the use phase. Further input flows from throughout Europe are considered during the use phase, e.g. washing powder.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the key parameters and assumptions for the washing machines.

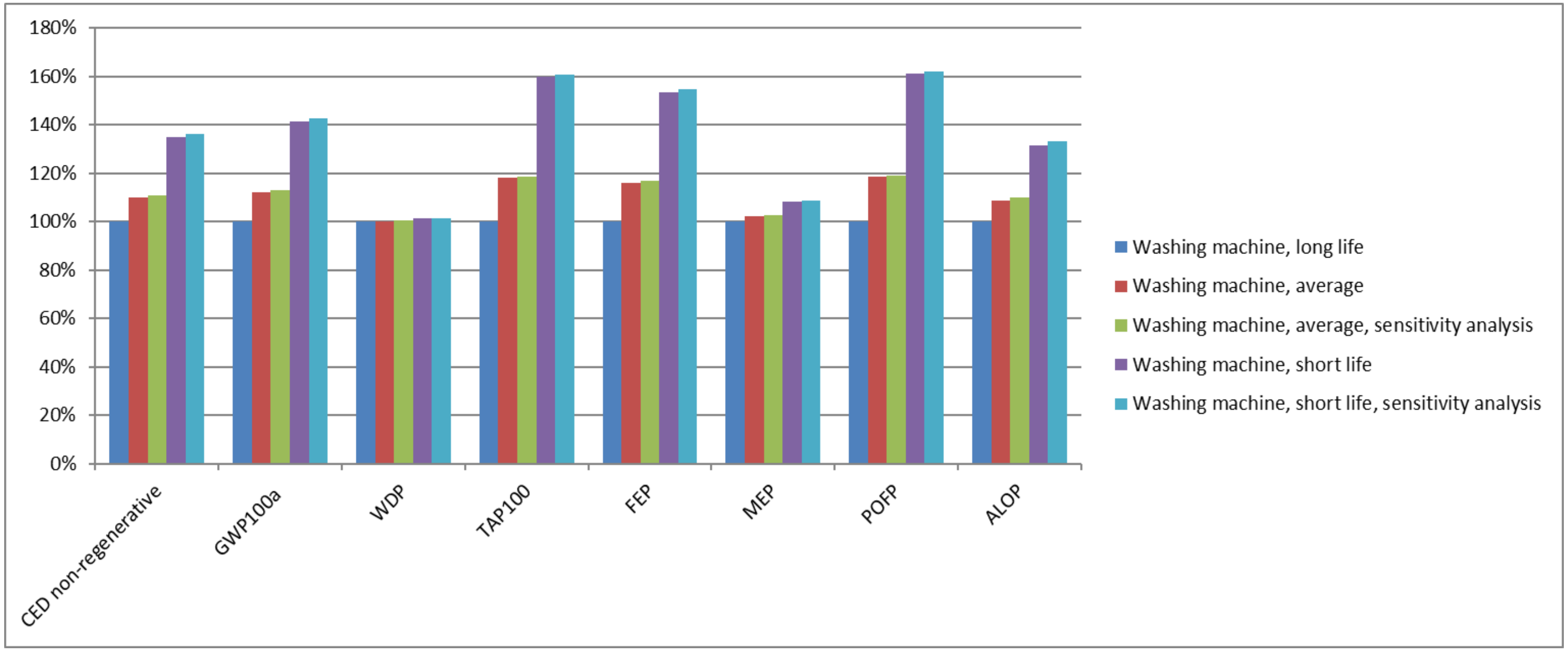
Table 88 Parameters for the washing machines

Washing machines	
Reference product	A durable washing machine according to Gensch and Blepp (2014)
Observation period	20 years (2011–2031)
Lifespan	Durable washing machine: 20 years Average washing machine: 10 years Short-life washing machine: 5 years
Manufacture	After Gensch and Blepp (2014)
Distribution	After Gensch and Blepp (2014)
Use	After Gensch and Blepp (2014): 0.65 kWh/wash, 158 washes p.a., 102.7 kWh per year (Energy efficiency class A+++) Taking into account the development of the electricity mix for the relevant years of use (according to BMUB 2012).
End-of-life	After Gensch and Blepp (2014)
Assumptions	The material input for the average washing machine is 25% lower than for the long-life washing machine. The material input for the short-life washing machine is 35% lower than for the long-life washing machine. Energy efficiency increase: 10% in 10 years (= per generation change)
Sensitivity analysis	Energy efficiency increase 5% in 10 years (= per generation change)

Depending on the lifespan of the appliances, it would be necessary to purchase either no new appliance (long-life), one further new appliance (average) or three further new appliances (short-life).

In the following, the results of the comparative life-cycle assessment for the washing machines are presented:

Figure 91 Impact assessments for short-life, average and long-life washing machines (over 20 years)



Source: Our presentation

Table 89 Life-cycle assessments for short-life, average and long-life washing machines (over 20 years)

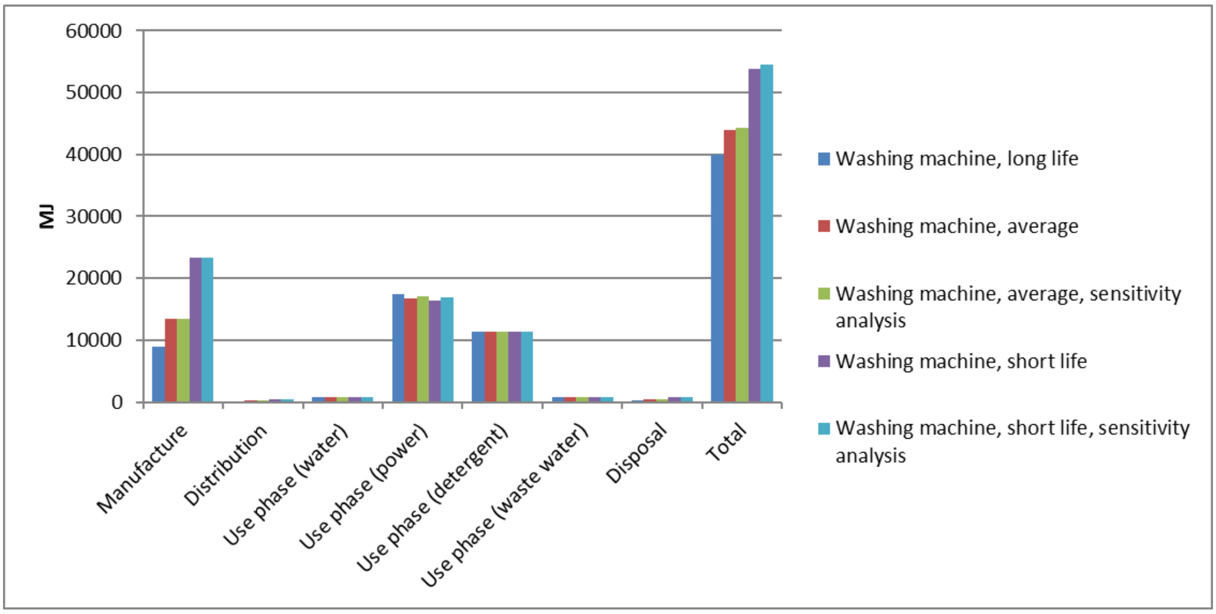
Category	Unit	Washing machine, long-life	Washing machine, average	Washing machine, average, Sensitivity analysis	Washing machine, short-life	Washing machine, short-life, Sensitivity analysis
$CED_{non\text{-}regenerative}$	MJ	39 967.9	43 935.6	44 310.2	53 897.0	54 464.5
GWP_{100a}	kg CO_2-eq	2 656.0	2 974.9	2 999.6	3 754.8	3 792.2
WDP	m^3	294.9	295.6	296.1	298.7	299.4
TAP_{100}	kg SO_2-eq	11.4	13.5	13.6	18.3	18.4
FEP	kg P-eq	2.4	2.8	2.8	3.7	3.7
MEP	kg N-eq	4.5	4.6	4.6	4.8	4.8
POFP	kg NMVOC	7.7	9.1	9.2	12.4	12.5
ALOP	m^2a	232.4	252.3	255.1	305.6	309.8

Figure 91 and **Fehler! Verweisquelle konnte nicht gefunden werden.** show that the environmental impact of a short-life washing machine is higher for all investigated environmental indicators than the impacts of the average and long-life machines. Despite energy efficiency increases of the new washing machines and higher production costs of longer-life appliances, the shorter-life appliances are worse for all environmental indicators.

The cumulative energy demand (CED) and the global warming potential of a short-life washing machine are approx. 40% higher in comparison with a long-life washing machine (Figure 92, Figure 93, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**). The acidification potential of a short-life washing machine is approx. 60% higher than for a long-life appliance. The difference between a long-life washing machine and an average washing machine is relatively small, but the long-life washing machine is still better in most environmental categories.

Over a period of 20 years, a long-life washing machine causes some 1100 kg less CO_2e emissions than the short-life appliance. The production-related greenhouse gas emissions account for approx. 47% of the overall greenhouse gas emissions for the short-life washing machine over a period of 20 years (Figure 93, **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 92 Cumulative energy demand (non-regenerative) of a short-life, average and long-life washing machine over 20 years

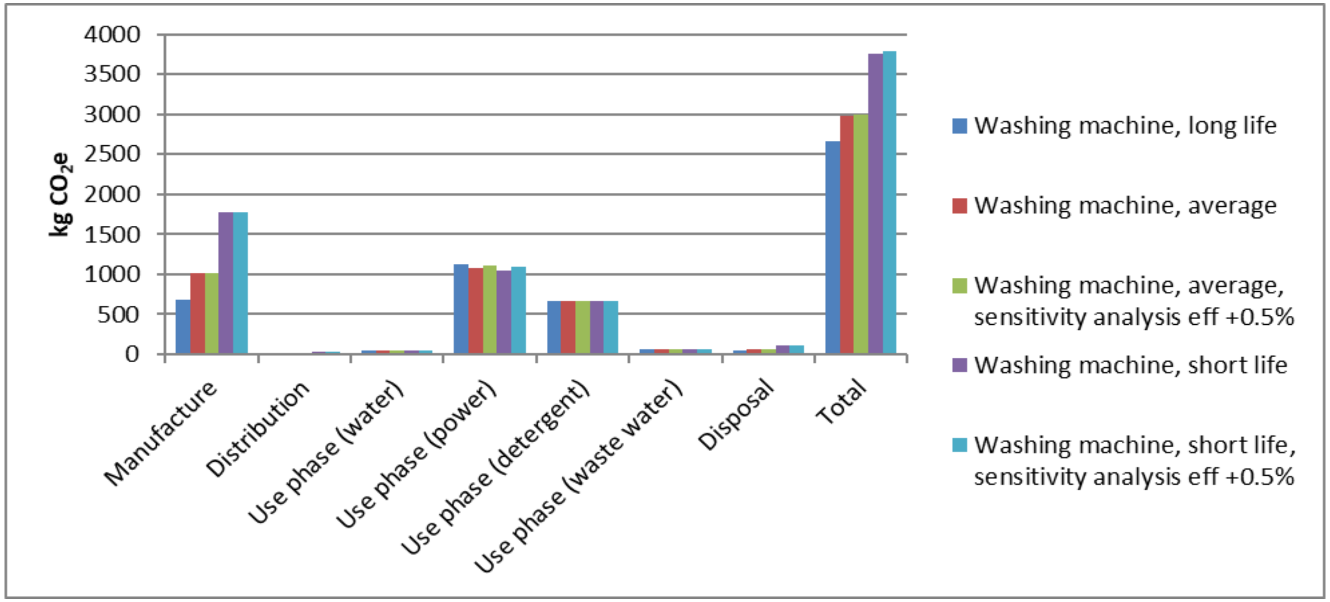


Source: Our presentation

Table 90 Cumulative energy demand (MJ) of a short-life, an average and a long-life washing machine (over 20 years)

CED non-regenerative [MJ]	Manufacture	Distribution	Use phase				Disposal	Total
			Water	Electricity	Washing powder	Waste water		
Washing machine, long-life	8,961	172	857	17,498	11,370	810	301	39,968
Washing machine, average	13,442	258	857	16,749	11,370	810	451	43,936
Washing machine average, Sensitivity analysis	13,442	258	857	17,123	11,370	810	451	44,310
Washing machine, short-life	23,299	447	857	16,363	11,370	810	751	53,897
Washing machine, short-life, Sensitivity analysis	23,299	447	857	16,931	11,370	810	751	54,465

Figure 93 Global warming potential (kg CO_2e) of a short-life, average, and long-life washing machine over 20 years



Source: Our presentation

Table 91 Global warming potential (kg CO2e) of a short-life, average, and long-life washing machine over 20 years

GWP [kg CO_2-eq]	Manufacture	Distribution	Use phase				Disposal	Total
			Wasser	Strom	Washing powder	Waste water		
Washing machine, long-life	680	11	54	1,128	669	68	46	2,656
Washing machine, average	1,020	16	54	1,078	669	68	68	2,975
Washing machine average, Sensitivity analysis	1,020	16	54	1,103	669	68	68	3,000
Washing machine, short-life	1,768	27.98	54.42	1,053	669.21	68.43	113.88	3,755
Washing machine, short-life, Sensitivity analysis	1,768	27.98	54.42	1,090	669.21	68.43	113.88	3,792

7.1.3 Televisions

The functional unit is a television as used in an average private household. The reference year for the purchase of the televisions was 2011. The investigation covered a period of 10 years, i.e. until 2021.

Manufacture and distribution are considered globally, with use in Germany. This applies in particular for modelling the provision of electricity in the use phase. Further input flows from throughout Europe are considered during the use phase.

Table 92 Assessment parameters for televisions

Televisions	
Reference product	42" LCD TV on the basis of BOM: EuP Lot 5 (2007): 32" LCD-TV[91]
Observation period	10 years (2011–2021)
Lifespan	Short-life 5.6 years[92] Long-life 10 years
Manufacture	After EuP Lot 5 (2007), (BOM adapted to a 42" LCD-TV by the project team)
Distribution	After EuP Lot 5 (2007)
Use	1st appliance: 219 kWh/year; after Prakash et al. (2014a) 2nd appliance: 208.5 kWh/year; calculated on the basis of Prakash et al. (2014a) Taking into account the development of the electricity mix for each year of use (after BMUB 2012)
Assumptions	Characteristics of a short-life product: no major software maintenance, mostly without updates. Characteristics of a long-life product: long software maintenance; hard drive and power-supply board exchanged once in the observation period. Repair and refitting by service technicians were taken into consideration.
Sensitivity analysis	The production cost of the long-life product is 10% higher than the short-life product.

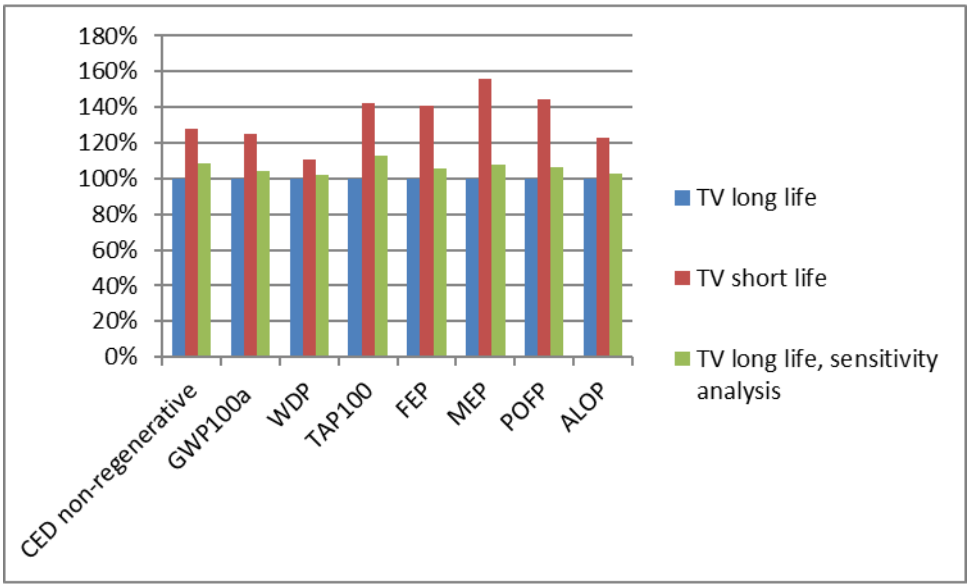
Depending on the lifespans of the appliances, over the duration of the comparison either a single appliance is considered (long-life) or an appliance with an additional replacement purchase (short-life). For the long-life television set, the exchange of the hard drive and the power-supply board (including the production cost) are considered. The environmental impact of software maintenance could not be included due to lack of data.

In the following, the results are presented for the environmental comparison.

[91] EuP Lot 5 (2007): Preparatory studies for eco-design requirements of EuP, Lot 5: Consumer electronics (TV), Stobbe, L.; Schischke, K.; with Graulich, K.; Gensch, C.-O.; Quack, D. and Zangl, S.; Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM) in cooperation with Öko-Institut e.V.; PE Europe; Codde; Bio Intelligence Service & Deutsche Umwelthilfe; 2007, Commissioned by EU Commission, DG TREN, Brussels

[92] The second short-life appliance was including proportionally over the remaining period.

Figure 94 Environmental impacts of a short- and long-life television (over 10 years)



Source: Our presentation

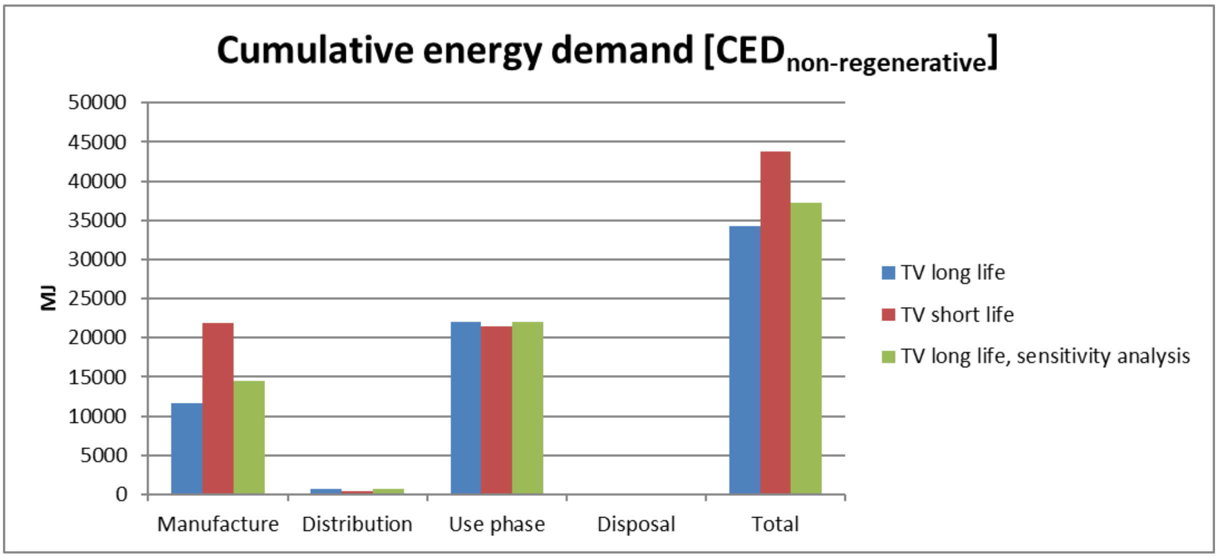
Table 93 Environmental impacts of a short- and long-life TV set over 10 years

Impact category	Units	TV long-life	TV short-life	TV long-life; Sensi
$CED_{non-regenerative}$	MJ	34 270.1	43 850.0	37 184.6
GWP_{100a}	kg CO_2-eq	2 465.1	3 088.3	2 560.7
WDP	m^3	24.4	27.0	24.8
TAP_{100}	kg SO_2-eq	10.3	14.7	11.7
FEP	kg P-eq	3.3	4.6	3.5
MEP	kg N-eq	3.08	4.8	3.33
POFP	kg NMVOC	6.7	9.75	7.19
ALOP	m^2a	159.96	196.8	164.0

Figure 94 and **Fehler! Verweisquelle konnte nicht gefunden werden.** show that the environmental impact of a short-life television is higher than that of a long-life television for all investigated environmental indicators. Despite the improved energy efficiency of new televisions, and the higher production cost of a long-life appliance (sensitivity analysis), the shorter-lived television performs worse for all environmental indicators.

Acidification potential is some 42% higher for a short-life television in comparison with a long-life appliance. Cumulative energy demand (CED) of a short-life television is 28% higher and the global warming potential is 25% higher than for a long-life television (see Figure 95, Figure 96, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 95 **Cumulative energy demand (non-regenerative) of short- and long-life TV set over 10 years**

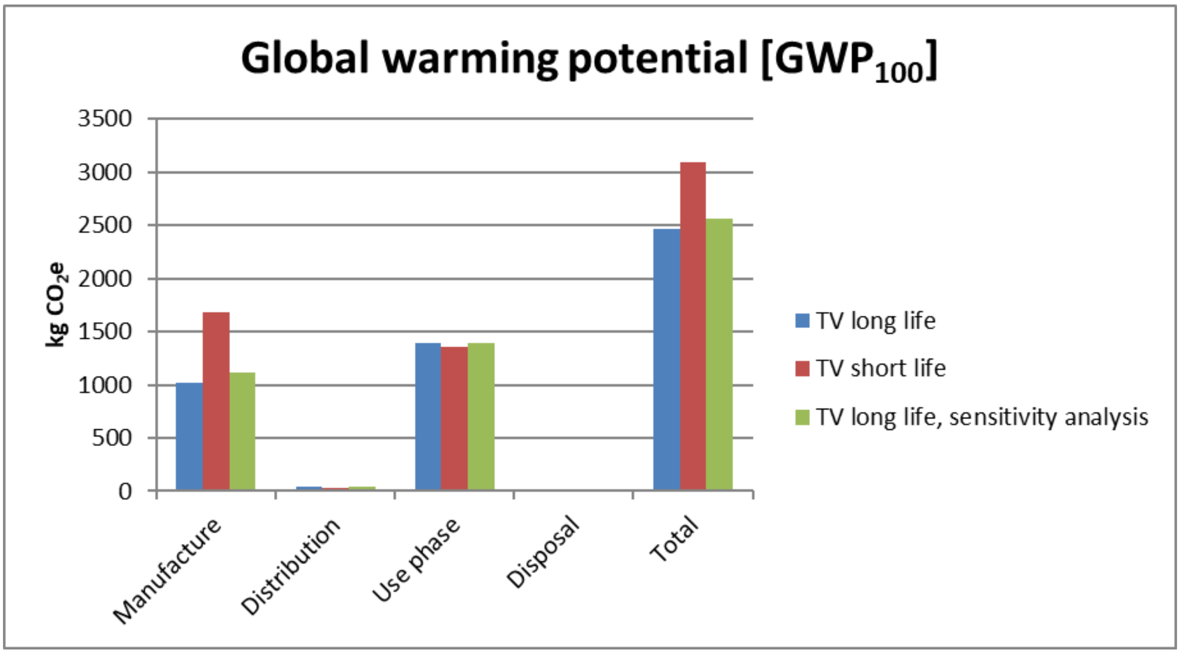


Source: Our presentation

Table 94 **Cumulative energy demand of short- and long-life televisions over 10 years**

CED non-regenerative [MJ]	Manufacture	Distribution	Use phase	disposal	Total
TV long-life	11 577	650	22 007	36	34 270
TV short-life	21 841	473	21 476	60	43 850
TV long-life sensitivity analysis	14 492	650	22 007	36	37 185

Figure 96 **Global warming potential (kg CO_2e) of the short- and long-life televisions over 10 years**



Source: Our presentation

Table 95 Global warming potential (kg CO2e) der short- and long-life televisions (Over 10 years)

GWP [kg CO_2-eq]	Manufacture	Distribution	Use phase	Disposal	Total
TV long-life	1017	43	1395	10	2465
TV short-life	1680	31	1361	17	3088
TV long-life, Sensitivity analysis	1113	43	1395	10	2561

Over a period of 10 years, a long-life TV set generates some 600 kg less CO2e than the short-life appliance. The production-related greenhouse gas emissions of a short-life TV account for approx. 54% of total greenhouse gas emissions over 10 years. For the long-life appliance, production-related greenhouse gas emissions account for approx. 41% of total greenhouse gas emissions over a period of 10 years.

7.1.4 Laptops

The functional unit is a laptop as used in an average private household. The reference year for the purchase of the laptops was 2011. The investigation covered a period of 12 years, i.e. until 2023.

Manufacture and distribution are considered globally, with use in Germany. This applies in particular for the modelling of the relevant electricity provision in the use phase. Further input flows from throughout Europe are considered during the use phase.

Fehler! Verweisquelle konnte nicht gefunden werden. presents the key costing parameters and assumptions for lap-top computers.

Table 96 Costing parameters for laptops

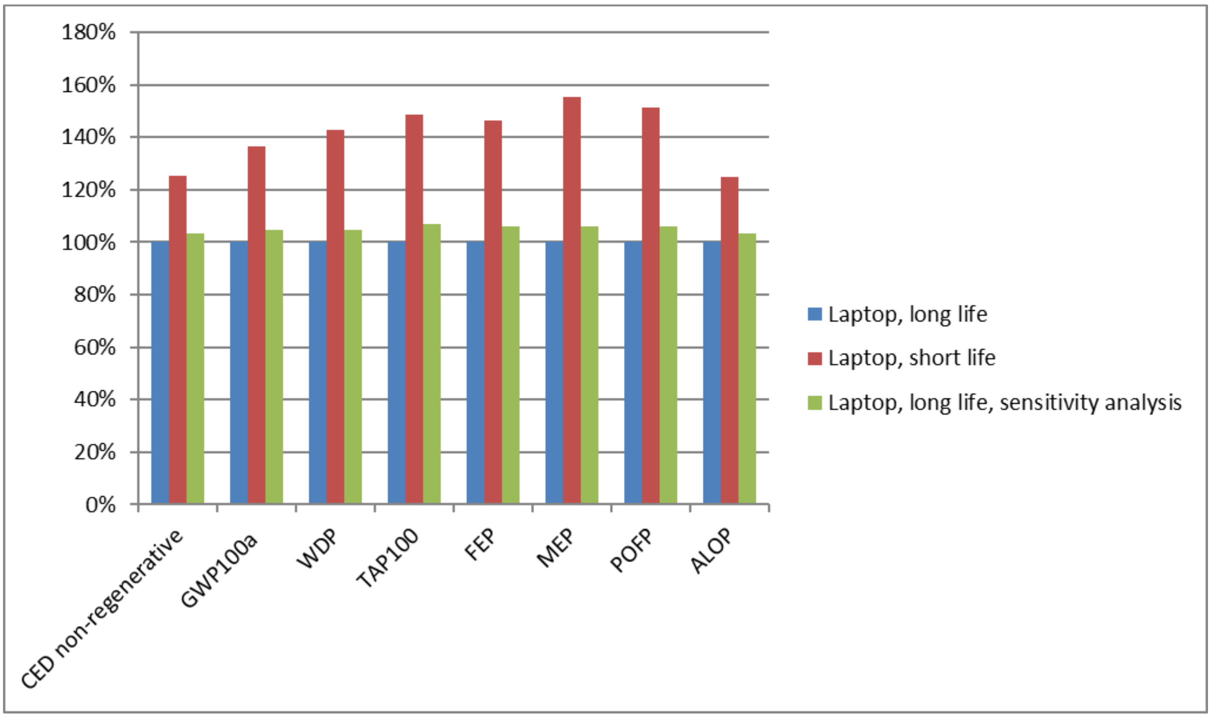
Laptops	
Reference product	ecoinvent 3.01
Observation period	12 years (2011–2023)
Lifespan	Long-life laptop: 6 years Short-life laptop: 3 years
Manufacture	After ecoinvent 3.01
Distribution	After Prakash et al. (2012)
Use	After Prakash et al. (2014a), 58 kWh p.a. Taking into account the development of the electricity mix for each year of use (according to BMUB 2012)
End-of-Life	After ecoinvent 3.01
Assumptions	Features of a short-life product: battery, hard drive and keyboard cannot be exchanged. Features of a long-life product: battery and hard drive can be exchanged; keyboard durable/reparable.

Laptops	
	For the long-life product, battery and hard drive must be replaced once in 6 years; keyboard is repaired once. From the 2nd exchange, the HDD-hard drive is replaced by an SSD drive. Repair and refitting by service technicians was taken into consideration. The new appliance is 5% more energy efficient than the replaced appliance.
Sensitivity analysis	The production cost of the long-life product is 10% greater than that of the short-life product.

Over the lifespan of the devices, either one further new appliance (long-life) or 3 further new appliances (short-life) would be purchased. Also taken into consideration was re-fitting the long-life appliance with a battery and hard drive/SSD (including their production costs) and the repair of the keyboard.

In the following, the results of the impact assessments for laptops are presented:

Figure 97 Impact assessment for a short- and long-life laptop (over 12 years)



Source: Our presentation

Table 97 Impact assessment for a short- and long-life laptop (over 12 years)

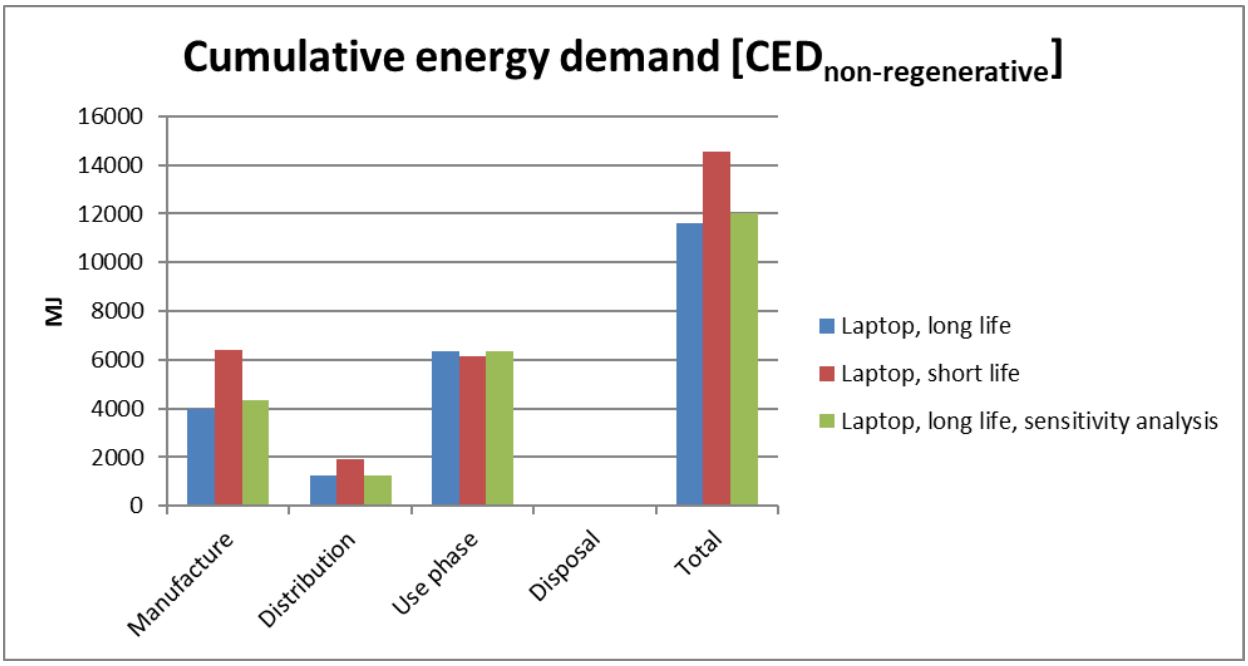
Category	Units	Laptop, long-life	Laptop, short-life	Laptop, long-life; Sensi
CED $_{non-regenerative}$	MJ	11 627.8	14 553.9	12 024.9
GWP_{100a}	kg CO_2-eq	900.6	1 228.1	941.0
WDP	m^3	11.6	16.6	12.2
TAP_{100}	kg SO_2-eq	3.3	4.8	3.5

Category	Units	Laptop, long-life	Laptop, short-life	Laptop, long-life; Sensi
FEP	kg P-eq	1.1	1.5	1.1
MEP	kg N-eq	0.46	0.7	0.49
POFP	kg NMVOC	2.2	3.39	2.37
ALOP	m^2a	47.29	59.0	48.9

Figure 97 and **Fehler! Verweisquelle konnte nicht gefunden werden.** show that the environmental impacts of a short-life laptop for all environmental indicators are higher than for the long-life laptop. Despite the improved energy efficiency of new laptops and the higher production cost of a long-life appliance (sensitivity analysis) the shorter-life laptop performs worse for all environmental indicators.

Acidification potential is 49% higher for a short-life laptop in comparison with a long-life appliance. The cumulative energy demand (CED) of a short-life laptops is 25% higher and the global warming potential is 36% higher in comparison with a long-life laptop (see Figure 98, Figure 99, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 98 Cumulative energy demand of the short-life and long-life laptops over 12 years



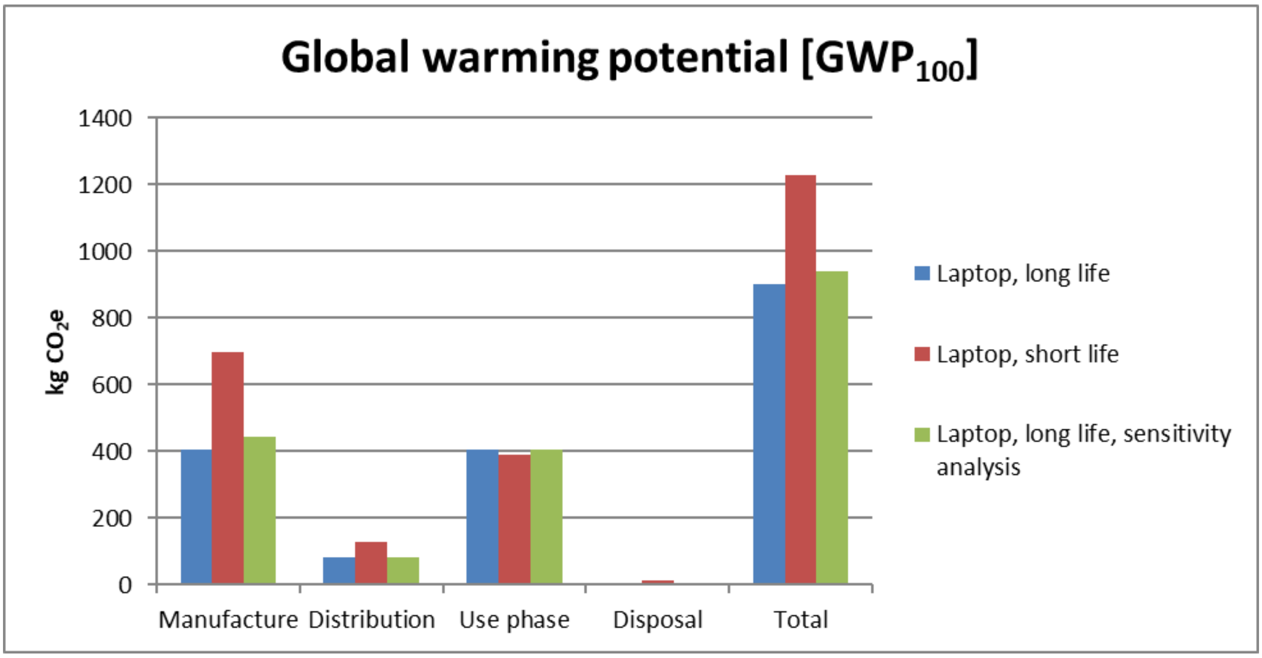
Source: Our presentation

Table 98 Cumulative energy demand (MJ) of the short- and long-life laptop (over 12 years)

CED non-regenerative [MJ]	Manufacture	Distribution	Use phase	Disposal	Total
Laptop, long-life	3 971	1 257	6 378	22	11 628
Laptop, short-life	6 425	1 920	6 170	39	14 554

CED non-regenerative [MJ]	Manufacture	Distribution	Use phase	Disposal	Total
Laptop, long-life, Sensitivity analysis	4 368	1 257	6 378	22	12 025

Figure 99 Global warming potential (kg CO_2e) der short- and long-life laptops (over 12 years)



Source: Our presentation

Table 99 Global warming potential (kg CO2e) der short- and long-life laptops (Over 12 years)

GWP [kg CO_2-eq]	Manufacture	Distribution	Use phase	Disposal	Total
Laptop, long-life	405	84	404	8	901
Laptop, short-life	696	128	391	13	1.228
Laptop, long-life, Sensitivity analysis	445	84	404	8	941

Over a period of 12 years, a long-life laptop leads to the release of some 300 kg less CO_2e than the short-life appliance. The proportion of production related greenhouse gas emissions of a short-life laptop represents approx. 56% of the total greenhouse gas emissions over a period of 12 years. For the long-life appliance, the production related greenhouse gas emissions represent approx. 44% of the total greenhouse gas emissions over a period of 12 years.

7.2 Economic comparative analysis

7.2.1 Methodological approach

Life cycle costing (LCC) assesses all costs associated with a certain product throughout its life that are borne by the actors in the life-cycle of this product (cf. Griesshammer et al. 2004 and

2007; Hunkeler et al. 2008). An important principle is to take into account the entire (physical) life-cycle of the product in question (i.e. as a rule one production unit), covering mainly the production, use, disposal, and where appropriate also transport. The appropriate costs for each phase are taken into account in the calculations (Rüdenauer 2011).

Life-cycle costs must be calculated on an actor-specific basis, e.g. all costs are registered that are relevant for the manufacturer, or for the user of the product. As with life-cycle assessments, life-cycle costing is based on the specified use and quantified with the aid of the functional units (cf. EN ISO 14040:2006 and EN ISO 14044:2006). The functional unit is the reference point for all calculations and results (Rüdenauer 2011).

In the literature, a distinction is made between three main types of life-cycle costs: (1) Conventional LCC, (2) Environmental LCC, (3) Societal LCC (UNEP/SETAC 2011). An important distinction between these basic types relates to the inclusion of external effects (e.g. social costs of electricity production). For the conventional LCC, no external costs are included. For the environmental LCC, those external costs are included whose internalisation is expected in the period relevant for the decision. And finally, for the societal LCC all external effects and the associated costs are taken into consideration, even if it is difficult to monetarise these and it may be necessary to include them in a qualitative form (Rüdenauer 2011).

In this study, the conventional LCC method is used. This only considers internal costs, i.e. real flows of money for one of the actors (in this case the user), and in some cases does not cover all phases of the life-cycle. The conventional LCC only involves a purely financial assessment of various (investment) alternatives (Rüdenauer 2011).

The cost elements used in this study for life-cycle cost calculations are presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**:

Table 100 Life-cycle costs from the point of view of consumers

Actor	Life-cycle costs		
	Purchase	Use	Disposal
Consumers	Purchase price (+ delivery and installation)	Operating costs Power costs Water costs etc. Further costs Maintenance Repairs	Collection Recycling

The life-cycle costs for washing machines, televisions and laptops are calculated in terms of the parameters and scenarios specified in **Fehler! Verweisquelle konnte nicht gefunden werden.**, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**. Real data on the purchase prices could not be collected for this study. For short-life appliances, values were used for the lower price category products in the online platform www.idealo.de. The prices for the longer-life appliances are derived from the product prices of leading brands that are acknowledged to produce higher-quality products. It was assumed that the higher-quality and longer-lived products would be more expensive than short-life appliances due to the material and design choices, the high standards of quality management in the supply chain and the extensive lifespan testing. However, there is not always a linear correlation between price and lifespan. For this reason, the calculated life-cycle costs can only offer a first orientation. The exact life-cycle costs depend on the specific case and a real product comparison might lead to different results.

The following life-cycle cost calculation represents a simplified account for short- and longer-life products. Other economic factors such as the development of energy prices, inflation and general rates of price increases were not taken into consideration. However, for the purposes of this study, the calculated life-cycle costs provide a sound basis for general conclusions.

7.2.2 Washing machines

Fehler! Verweisquelle konnte nicht gefunden werden. shows the cost elements used to calculate the life-cycle costs for a short-life, an average and a long-life washing machine:

Table 101 Cost elements to determine the life-cycle costs of a short-life, an average and a long-life washing machine

Cost element	Cost (€)	Source
Purchase price of a short-life washing machine	350	www.idealo.de
Purchase price of an average washing machine	600	Our assumption
Purchase price of a long-life washing machine	1000	Our assumption
Electricity price	€ 0.298 /kWh	EcoTopTen 2015, www.ecotopten.de
Water price	€ 3.98 /m³	EcoTopTen 2015, www.ecotopten.de
Power consumption	102.7 kWh p.a.	After Gensch & Blepp (2014)
Water consumption	48.2 litres per wash	After Gensch & Blepp (2014)
Disposal costs	None[93]	-
Assumption	Energy efficiency increase: 10% in 10 years	

Figure 100 shows the annual total costs, consisting of the proportional purchase costs and the costs for power consumption and repairs. For the long-life washing machine with a 20-year lifespan the annual total costs are lowest. In comparison, a short-life washing machine with a 5-year lifespan incurs approx. 13% more costs.

In summary, there is only a marginal difference between a short-life, an average (10-year lifespan) and a long-life washing machine. This effect is attributable to the comparatively high purchase price of a long-life washing machine. If the price of the long-life washing machine was any higher, and the assumed increase in energy efficiency when changing from one appliance to the next was much greater, then the long-life washing machine would have even higher annual total costs than short-life and average appliances. Furthermore, it was assumed that a long-life washing machine would not require any repairs over its lifetime. If repairs and spare parts are necessary, this would increase the costs for the long-life washing machine. Conversely, the long-

93 Since 24 March 2006, the manufacturer has been (financially) responsible for taking back old appliances and disposing of them. Therefore, no additional disposal costs are assumed.

life washing machine would have led to greater savings if the difference in the purchasing costs between short-life and long-life appliances were smaller.

Figure 100 Annual total costs (in EUR) of a short-life, an average and a long-life washing machine

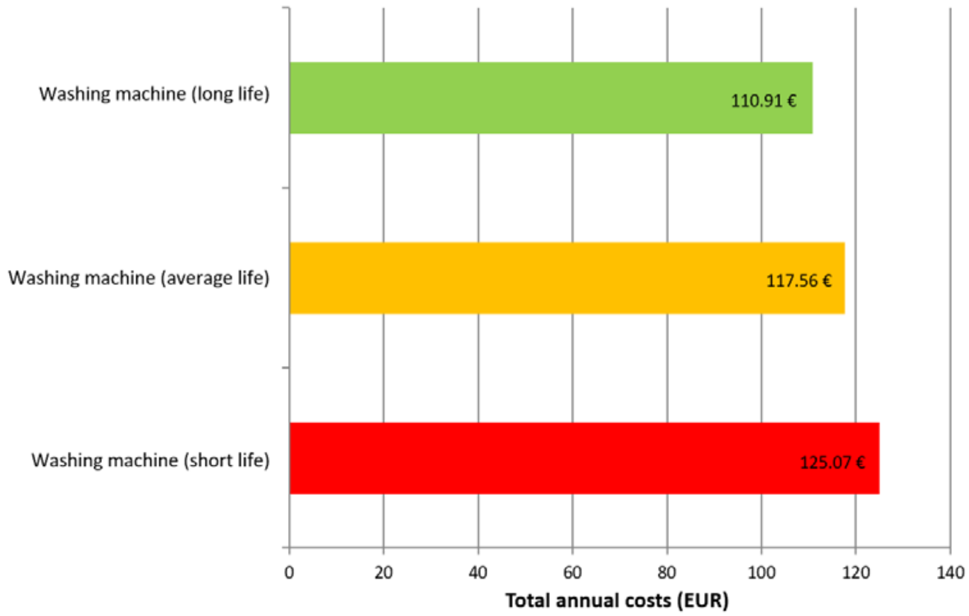
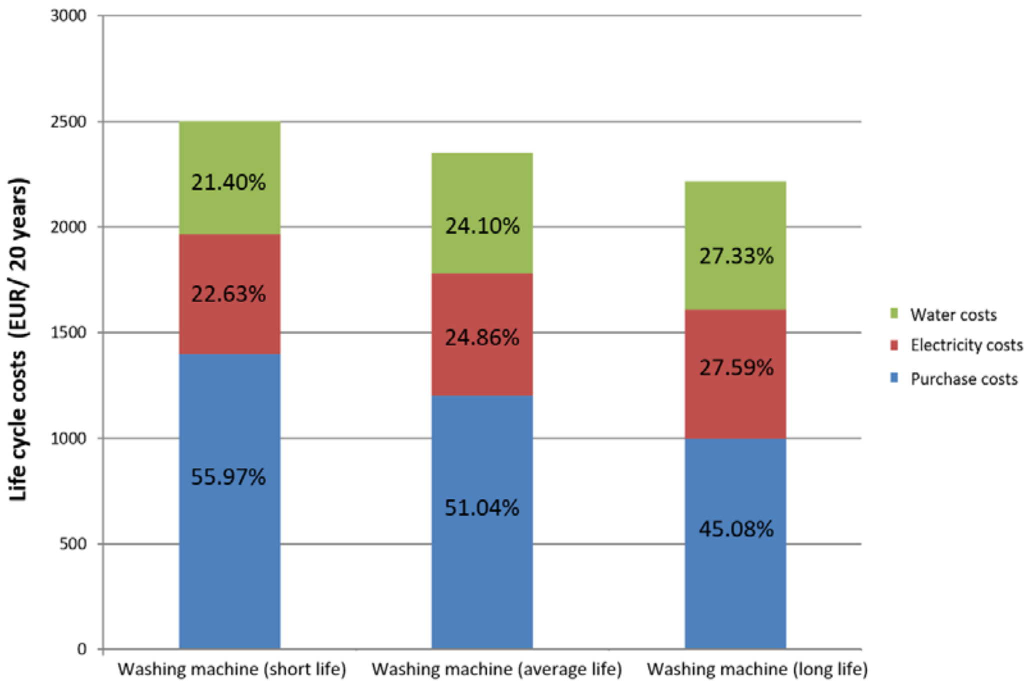


Figure 101 shows the accumulated life-cycle costs of a short-life, an average and a long-life washing machine. Compared with a short-life washing machine, it is possible to save approx. € 283 in 20 years by buying a long-life washing machine. Even the average washing machines cost approx. € 150 less over 20 years than the short-life appliance. On the basis of the assumptions made in this study, the purchase price of the long-life washing machine would have to be approx. 270% higher than that of the short-life appliance (in this example approx. € 1290) if it were to exceed the life-cycle costs of the short-life washing machine.

Figure 101 Life-cycle costs (accumulated over 20 years) of a short-life, an average and a long-life washing machine



7.2.3 Televisions

Fehler! Verweisquelle konnte nicht gefunden werden. shows the assumed cost elements for calculating the life-cycle costs of a short- and long-life television:

Table 102 Cost elements for calculating the life-cycle costs of a short- and a long-life TV

Cost element	Cost (€)	Source
Purchase price of a short-life TV (42 inch)	350	www.idealo.de
Purchase price of a long-life TV (42 inch)	600	Our assumption
Replacement hard drive (HDD)	60	www.billiger.de (average)
Replacement power supply card	50	Section 6.2.4
Electricity price	€ 0.298 /kWh	EcoTopTen 2015, www.ecotopten.de
Power consumption	Appliance 1: 219 kWh/year; Appliance 2: 208.5 kWh/year	After Prakash et al. (2014a)
Labour costs, new hard drive (HDD)	€ 50	Our assumption
Labour costs, new power supply card	€ 110	Section 6.2.4
Disposal costs	None[94]	-

[94] Since 24 March 2006, the manufacturers have been (financially) responsible for taking back and disposing of old appliances. Therefore, no additional disposal costs are assumed.

Figure 102 shows the annual total costs, consisting of the proportional purchase costs and the costs for power consumption and repairs. The annual total costs are lowest for a long-life TV which does not have to be repaired at all over its lifespan of 10 years. However, the difference to the short-life appliance is almost negligible because of the high price of the long-life TV. As with the washing machines, the long-life TV would have higher annual total costs if the price was much higher than assumed. Conversely, the long-life appliance would have led to greater savings if the difference between the purchase costs of the short-life and long-life appliances had been smaller.

It should be noted that the annual total costs of a short-life TVs (lifespan 5.6 years) are lower than those of a long-life TV that has to be repaired in the course of its lifespan. The comparatively high costs for the long-life TV in this example are due to the high purchase price in combination with the high repair costs (HDD and power supply card).

Figure 102 Annual total costs of a short-life and a long-life TV

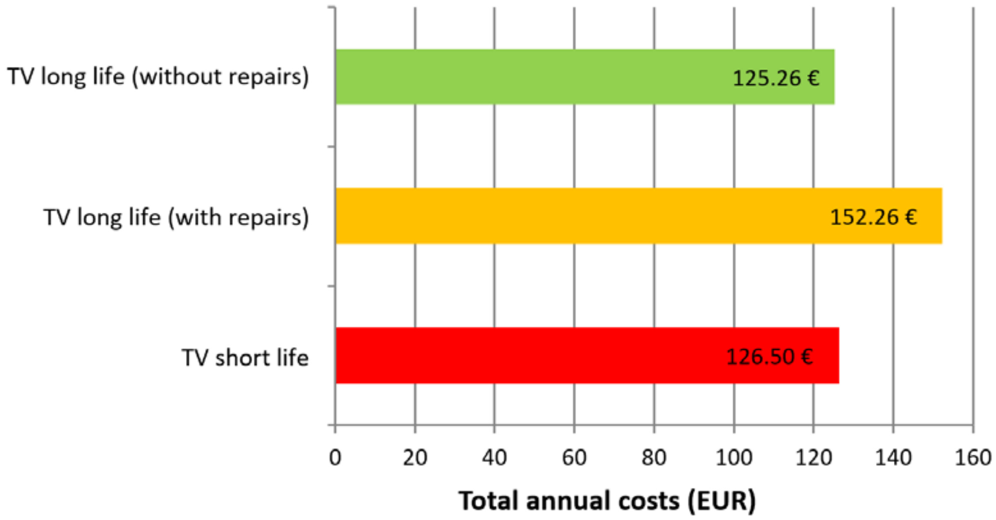
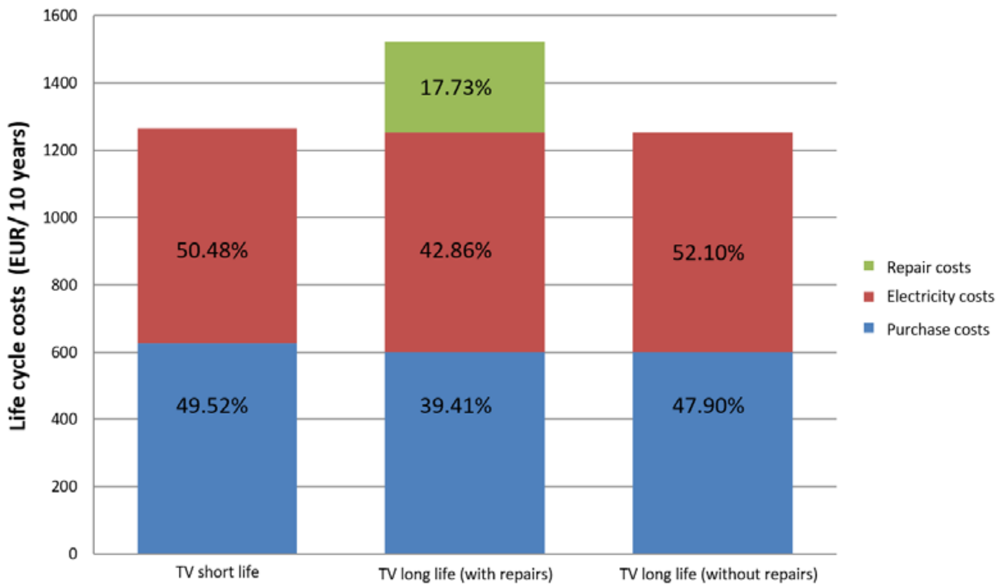


Figure 103 shows the accumulated life-cycle costs of a short-life and a long-life TV set. It is clear that repair costs have a considerable effect on the overall result for a long-life TV. On the basis of the assumptions made in this study, a long-life TV would have to have a purchase price approx. 75% higher than the short-life appliance (in this example approx. € 613) if it were to exceed the life-cycle costs of the short-life TV.

Figure 103 Life-cycle costs (accumulated over 10 years) of a short-life and a long-life TV



7.2.4 Laptops

Fehler! Verweisquelle konnte nicht gefunden werden. shows the assumed cost elements for calculating the life-cycle costs of a short- and long-life laptops:

Table 103 Cost elements for calculating the life-cycle costs of a short- and a long-life laptop

Cost element	Cost (€)	Source
Purchase price of a short-life laptop	350	www.idealo.de
Purchase price of a long-life laptop	600	Our assumption
Replacement SSD (solid state drive)	129	www.idealo.de
Replacement battery	40	Section **Fehler! Verweisquelle konnte nicht gefunden werden.**
Power price	€ 0.298 /kWh	EcoTopTen 2015, www.ecotopten.de
Power consumption	58 kWh p.a.	After Prakash et al. (2014a)
Repair labour costs, SSD	€ 40	Our assumption: Repair takes 1 hour
Repair labour costs, keyboard	€ 40	Our assumption: Repair takes 0.5 hour
Disposal costs	None[95]	-
Assumption	The new appliance is 5% more energy efficient than the replaced appliance	

Figure 104 shows the annual total costs, consisting of the proportional purchase costs and the costs for power consumption and repairs. The annual total costs are lowest for the long-life laptop that does not have to be repaired at all over its lifespan of 6 years. In comparison, a short-life laptop would incur approximately 14% more costs every year.

The annual total costs of a long-life laptop that requires various relatively expensive repairs in order to achieve a six-year lifespan are higher than those of a short-life laptop with a lifespan of 3 years. (It was assumed that the hard drive and the battery of a long-life laptop would have to be replaced once in 6 years and the keyboard would have to be repaired once.)

[95] Since 24 March 2006, the manufacturer has been (financially) responsible for taking back and disposing of old appliances. Therefore, no additional disposal costs are assumed.

Figure 104 Annual total costs of a short-life and a long-life laptop

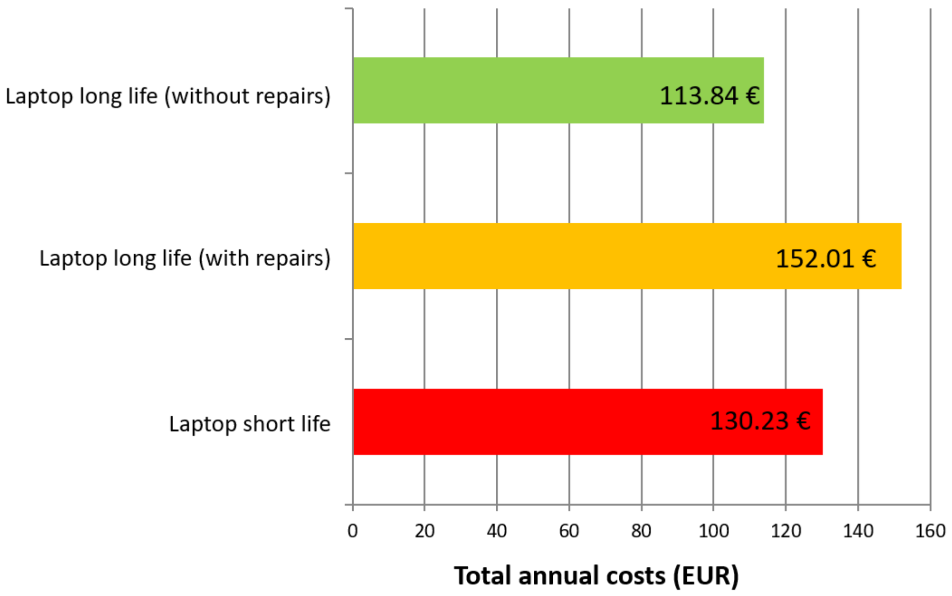
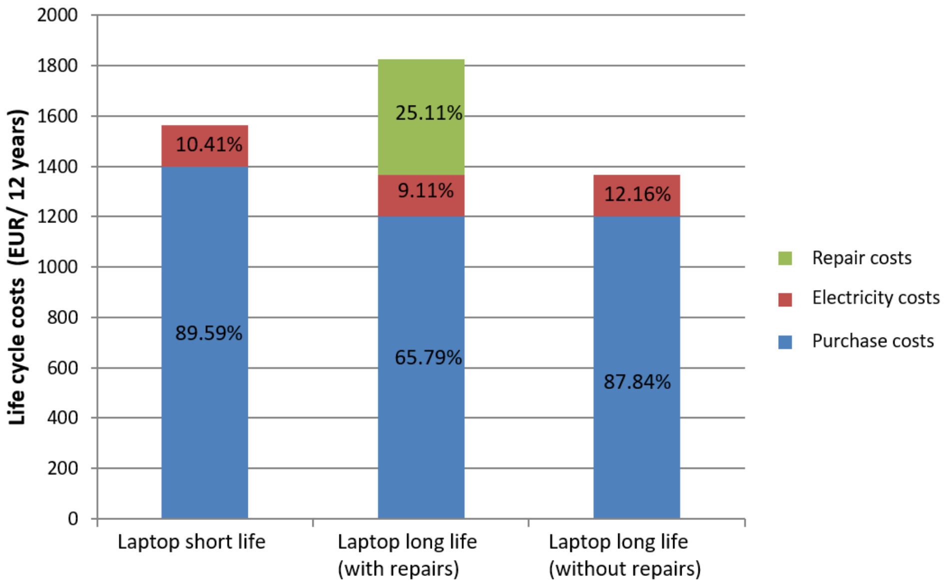


Figure 105 shows the accumulated life-cycle costs of a short-life and a long-life laptop. In comparison with a short-life laptop, buying a long-life laptop which required no repairs would lead to a saving of approx. € 196 in 12 years. For a long-life laptop requiring repairs, approx. € 261 more costs would incurred than for the short-life appliance over 12 years. On the basis of the assumptions made in this study, the purchase price of a long-life laptop would have to be nearly twice that of the short-life appliance (in this example approx. €700) if it were to exceed the life-cycle costs of the short-life laptop.

Figure 105 Life-cycle costs (accumulated over 12 years) of a short-life and a long-life laptop



Conclusions of the economic comparisons

The results of the economic comparisons in this study are highly dependent on the assumptions on which they are based. The assumed purchase costs for the long-life products in the study are based on the available appliances and brands in Germany. The difference in the purchase costs between short-life and long-life product variants is a key factor when judging savings or additional costs of a long-life product compared to a short-life appliance. If the difference is small, then as a rule there will be larger positive savings effects with long-life products. On the other hand, if the purchase cost of the long-life product was considerably higher than the cost of a short-life appliance, then the long-life product would do worse than the short-life product with regard to life-cycle costs, or the positive savings would be much lower. The second key assumption concerns the improvement in the energy efficiency of products. If the energy efficiency of a newly acquired short-life product is considerably better that the preceding generations and the difference in the acquisition costs between short- and long-life appliances is very large, then this would lead to smaller positive cost effects or even to negative cost effects for the long-life products.

8 Strategies against obsolescence

On the basis of the analysis of causes in Chapter 6, strategies can be developed against the obsolescence of electric and electronic equipment. The focus is on *technical and product-specific options and management strategies*. The main goal is to achieve an ensured minimum lifespan or to extend the period of use of electric and electronic equipment.

Legal and economic instruments that could support an extension of the product lifespan, e.g. the introduction of obligatory manufacturer warranties or a reduction in the rate of value-added tax for repair companies, are considered in two other UBA projects[96] and are therefore not considered in detail here.

The replacement of products that are still in working order due to psychological obsolescence is addressed in this study by means of strategies to improve consumer transparency, by increasing the information obligations of manufacturers, by reducing transaction costs for everyday decisions, and by the identification of incentive mechanisms for a longer period of product use. Possible measures from the fields of social innovation and cultural change, e.g. sufficiency, “using instead of owning”, changes in individual and collective consumer behaviour, etc., are investigated in depth in other UBA projects[97] and are not included in the options and strategies proposed here.

A wide range of reasons have been identified for product failures and for the replacement of the types of products covered by this study. However, similar patterns and trends can be found irrespective of the product group. It would therefore not seem helpful to formulate separate counter-measures for each individual reason for replacement, giving the impression of a comprehensive approach. This could have the result that the strategies would themselves become obsolete with every new product development or innovation. It seems more appropriate to consolidate the causes for failures and replacements in topic clusters. *Strategies against obsolescence* can then be defined that are independent of the product group and individual reasons for replacement and that apply *for the whole topic cluster*.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the topic clusters and the associated causes for failures and the replacement of washing machines, laptops, and televisions. Causes are classified in one of the following four main topic clusters:

1. Deficient mechanical and electronic robustness (material obsolescence)
2. Software-related reasons (functional obsolescence)
3. High cost of repairs compared with the prices of new products (economic obsolescence)
4. Trends and desire for new functionalities (psychological obsolescence).

The reasons identified for failures and replacements in the product groups washing machines, laptops and televisions were assigned to these topic clusters. This provides an overview of those causes of obsolescence that apply equally for all the product groups and which can therefore be tackled with horizontal strategies, and on the other hand those causes of obsolescence that need to be addressed with product-group specific approaches.

[96] “Stärkung eines nachhaltigen Konsums im Bereich Produktnutzung durch Anpassungen im Zivil- und öffentlichen Recht” (FKZ 3713 18 308) and “Entwicklung von Vorschlägen zum Einsatz von ökonomischen Instrumenten zur Steigerung der Ressourceneffizienz in Deutschland und der EU” (FKZ: 3712 93 105).

[97] For example www.umweltbundesamt.de/publikationen/soziale-innovationen-im-aufwind

Table 104 Description and allocation of the causes of obsolescence

Issue cluster for causes of obsolescence		Washing machines	Laptops	TV sets
1	Deficient mechanical and electronic robustness (material obsolescence)			
1.1	The lifespan targets set for the production are either not made available or are too short. The lack of transparency leaves consumers unable to make the best buying decisions as regards their own needs (asymmetrical information).	X	X	X
1.2	Components are not properly checked for adherence to lifespan requirements during production or at the approval stage.	X	X	X
1.3	Real time stress exposure is beyond benchmark lifespan requirements implemented in production.	X	X	X
1.4	The appliance as a whole is not sufficiently checked for adherence to lifespan requirements.	X	X	X
1.5	Various production series of the same product contain different components. Competition pressure creates volatility in the availability and quality of components. The quality standards of manufacturers (if any) cannot be implemented vertically into supply chains.	X	X	X
1.6	Poor design and heat management, e.g. ventilation slots that are blocked by dust and dirt particles which lead to the device overheating.		X	X
1.7	Short battery service life (useful life and capacity) limits use (electrochemical robustness); permanently fitted batteries are difficult or impossible to replace.		X	
2	Software-induced reasons (functional obsolescence)			
2.1	New TV formats appearing frequently (e.g. HD Ready, Full HD, UHD), new functionalities (e.g. HbbTV) and the resulting increase in source data[98] place greater requirements on both software and hardware.			X
2.2	Different transmission standards, a lack of standardisation of dynamic channel management and interfaces and conditional access systems.			X
2.3	For older components and peripheral devices (e.g. some graphics cards, printers, and scanners), manufacturers often stop releasing updated drivers for current operating systems, meaning that they can no longer be used properly.		X	

[98] See section 6.2.2 for more detail

Issue cluster for causes of obsolescence		Washing machines	Laptops	TV sets
2.4	Installing an up-to-date operating system on older laptops may no longer be possible due to their performance restrictions. If the minimum requirements of the operating system are not met, the operating system will be unable to run on the hardware in question and the device would need replacing despite not having yet reached its technical end of life.		X	
3	High cost of repairs compared with the prices of new products (economic obsolescence)			
3.1	For many defects, professional repairs seem too expensive in view of the current market prices for new products.	X	X	X
3.2	Excessive component integration, making replacement complex and expensive. Furthermore, poor accessibility of components.	X	X	X
3.3	No replacement parts or only original parts available.	X	X	X
3.4	Excessive call-out fee for servicing technicians[99].	X		(X)
4	Trends and desire for new functionalities (psychological obsolescence)			
4.1	Innovative features, new functionalities and promises of convenience in new devices lead customers to buy new products.	X	X	X
4.2	Socio-demographic factors, such as moving to a new apartment with fitted kitchen or handing down existing devices to younger family members.	X	X	X
4.3	Enhanced energy efficiency of new devices, e.g. replacing a desktop PC with a laptop[100].	X	X	X

Fehler! Verweisquelle konnte nicht gefunden werden. shows that most of the reasons for failures and replacements are independent of the product groups. These can therefore be tackled with horizontal strategies across product groups.

In **Fehler! Verweisquelle konnte nicht gefunden werden.**, strategies are proposed to address the reasons for failures and replacements identified in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The aim is that for a given topic cluster all the reasons for failures and

[99] Cf. section 6.2.4 and 6.7.4

[100] Prakash et al. (2012) have shown that the ecological cost of replacing an old laptop with a new and more energy-efficient model cannot be amortised in realistic time periods. This is why Prakash et al. (2012) suggest to use ICT devices as long as possible.
In another study Prakash et al (2012) have shown, that the ecological cost of replacing a workstation with a desktop PC with a workstation with a laptop also pays for itself in just under 9 to 10 years. This period is significantly longer than the expected and useful life of workplace computers in the federal administrations.

replacements should be addressed with the same strategies. In general, the strategies proposed in **Fehler! Verweisquelle konnte nicht gefunden werden.** address two equally important sectors of product policies:

- Strategies to achieve an ensured minimum lifespan and to extend the product lifespan,
- Strategies to extend the period of use of a product by the consumer.

The causal analysis in Chapter 6 has shown that a sizeable proportion of electric and electronic appliances are disposed of while they are still in working order. Aspects of both psychological and economic obsolescence play important roles.

In **Fehler! Verweisquelle konnte nicht gefunden werden.**, Strategy 1 addresses the product lifespan, while Strategies 2, 3, 4 and 5 the period of product use.

Strategies to counter "*Trends and desire for new functionalities*" (**Fehler! Verweisquelle konnte nicht gefunden werden.**, Cluster 4) are not considered in this project. (The remits of other UBA projects cover social innovation and cultural change.)

Table 105 Identifying strategies against obsolescence

Causes of obsolescence issue cluster		Strategies to counter obsolescence	
1	Deficient mechanical and electronic robustness	Strategy 1: Life-time requirements, standardisation, standards definition	
		S 1.1	Support of voluntary life-time tests using corresponding test standards and under critical test conditions
		S 1.2	Compulsory life-time tests under critical test conditions and specification of life-time in technical documentation and/or as part of consumer information
		S 1.3	Development of testing methods and standards for reviewing the life-time testing of components and devices
		S 1.4	Investigation of the influence of real-life use conditions on life-time and establishment of a standard with critical test conditions
		S 1.5	Design for longevity
		S 1.6	Additional testing of life-time by independent test institutes, such as the German consumer association Stiftung Warentest
2	Software induced conditions	Strategy 2: Minimum requirements for software	
		S 2.1	Development of innovative und modular software solutions
		S 2.2	Essential software drivers must be kept available and updated for a sufficiently long period
		S 2.3	Promotion of free-standing software and hardware initiatives and creation of legal framework for their use and commercialisation
		S 2.4	Compulsory hardware and software updates and full functionality tests
		S 2.5	Standardisation, fault diagnostics function and new software solutions
3		Strategy 3: Reparability	

Causes of obsolescence issue cluster		Strategies to counter obsolescence	
	High costs of repairs compared with the prices for new products	S 3.1	Improved framework conditions for independent and independent repair companies, including transparent repair information
		S 3.2	Mandatory specifications for maintaining availability of spare parts, including transparent information concerning anticipated costs of spare parts
		S 3.3	Batteries and other wear parts must be easy to replace or repair
		S 3.4	Changes to the cost calculations for repairs
		Strategy 4: Servicing models of manufacturers for extending life and use time	
		S 4.1	Leasing models (instead of ownership)
		S 4.2	Buy-back agreements
		S 4.3	Aftercare treatment as a service
4	General: shorter use periods by consumers[101]	Strategy 5: Information obligations, consumer information	
		S 5.1	Clear declaration of breaking points (in terms of functional safety), wear parts and maintenance intervals
		S 5.2	Consumer information on extending the period of use

The individual strategies against obsolescence are presented in more detail in **Fehler! Verweisquelle konnte nicht gefunden werden.** to **Fehler! Verweisquelle konnte nicht gefunden werden.**. In addition, a short assessment is given of the possible strengths and weaknesses of each strategy. Possible instruments are included that could be appropriate for the implementation of the various strategies.

This presentation is the result of numerous contacts with experts, ranging from discussions during a meeting with experts in December 2014 and a conference in June 2015[102], as well as in-depth research carried out in the course of this study.

It was not possible to carry out a comprehensive analysis of all the strategies presented here, but the strategies offer a good starting point for the detailed development of product policy measures relating to obsolescence. Further research is needed on the feasibility and practicability of some strategies. Reference is made to research requirements in the strategy descriptions and a summary is provided in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

A prioritisation or a ranking of the strategies recommended in the following tables in terms of effectiveness, cost and enforceability did not seem appropriate. The proposed strategies are coordinated with one another and address in equal parts the business sector, consumers, and policy-makers. This is intended to ensure that the effects of strategies directed to one group of

[101] This cross-cutting strategy can be assigned to various topic clusters, e.g. it can address “Deficient mechanical and electronic robustness”, because this brings together the lifespan tests and lifespan disclosure for consumers. On the other hand, transparent information about prospective repairs and their costs could influence choices in favour of a repair-friendly product. Despite the costs of the repairs, the calculations in this study have shown that life-cycle costs could be lower for the consumer than repeat purchases of new products.

[102] Conference Against Waste II – Strategies against obsolescence, 25 June 2015, Berlin; documentation under: www.umweltbundesamt.de/wider-die-verschwendung-ii-programm

actors is not diminished by counter-productive actions of other groups of actors. For example, the specification of a minimum lifespan or measures to extend the lifespan of a product (Target group: Manufacturers) only makes sense if the effects can be monitored (Target group: Policy makers) and implemented (Target group: Consumers).

Table 106 Strategy 1: Life-time requirements, standardisation, standards definition

Strategy 1: Life-time requirements, standardisation, standards definition	
S 1.1: Support of voluntary life-time tests using corresponding test standards and under critical test conditions	
Brief description	Development and/or identification of test standards for products/critical components that can be used for the measurement of the lifetime of an appliance. Manufacturers should be able to include details of the lifespan on the product packaging or in the documentation. Compliance with the test standards should be confirmed by independent accredited institutions[103].
Instrument	Disclosure of details of the lifespan could be institutionalised as a minimum requirement as part of Type-1 environmental labelling, e.g. the EU environmental label or 'Blue Angel' label.
Pro	The comparability of products will be improved.
Contra	Only the manufacturers of higher-value products will make such voluntary lifespan disclosures. The additional costs of the tests by independent external institutions will have to be borne by the customers. It is necessary to have the voluntary disclosures checked by an independent institution.
S 1.2: Compulsory life-time tests under critical test conditions and specification of life-time in technical documentation and/or as part of consumer information	
Brief description	A central point is that the appliance parts and components are optimised during design and manufacture for a certain lifespan and period of use. The lack of transparency means that consumers are not able to make the best choice on the basis of their own needs (asymmetric information). Therefore, it is necessary to have increased transparency about the expected lifespan of the product in the documentation[104]. The test conditions and the underlying assumptions should be specified by official bodies. The expected lifespan of all products must be disclosed for a specified user profile (in years or as a total of functional units). It is also conceivable that minimum lifespans could be introduced for specific product groups. If it not possible to measure the lifespan of an appliance in a timely way for an acceptable cost then quality and durability demands should be specified for the critical components. The suitability of existing safety and usability standards for parts and components for lifespan testing should be examined. Where appropriate, these should be extended to include lifespan and durability requirements, particularly for critical parts and components.

[103] The existing regulations for the 'Blue Angel' environmental label could be of assistance. These include the following requirement: "*The applicant presents test reports of an independent test laboratory accredited in accordance with EN ISO/EC 17025. Test reports of the applicant are recognised as equal if they use a test laboratory that is approved for these measurements by an independent body as a supervised manufacturer's testing laboratory*".

[104] The project "*Stärkung eines nachhaltigen Konsums im Bereich Produktnutzung durch Anpassungen im Zivil- und öffentlichen Recht*" (FKZ 3713 18 308) proposes an obligatory manufacturer's warranty statement (p. 154 f.). The manufacturer should have to make a statement about the lifespan, which could be "nought years" (Schlacke et al. 2015). According to Schlacke et al. (2015), the manufacturer would essentially only be obliged to give a (standardised) signal to the market; this would be a voluntary guarantee in accordance with Section 443, German Civil Code. As in the past, it would therefore be a competition parameter, in particular as a signal for high-quality products on markets where the consumers were uncertain about product quality. The requirement to make quality statements would highlight quality as an important marketing criterion and would improve transparency to the benefit of consumers.

Strategy 1: Life-time requirements, standardisation, standards definition	
	The disclosures should be examined and confirmed by independent and accredited institutions (see also Footnote 103).
Instrument	These measures should be implemented at the EU level and possibly be an additional criterion for CE labelling or a minimum requirement in accordance with the EU Eco-design Directive[105]. Introducing a requirement for the manufacturer/importer to order external third-party testing represents a considerable hurdle, but is in principle possible.
Pro	Comparability of products is ensured. For certain appliances and components, test standards and measurement regulations to determine the lifespan already exist or can be developed at a reasonable cost.
Contra	For many products and components, appropriate requirements and generally valid specifications will first have to be developed. The testing by external and independent test institutions is expensive and the costs will have to be borne by the customers. Market monitoring is already facing considerable challenges, so that even simply examining the results of the external test institutions would not be trivial. But if there were no systematic scrutiny this would clearly be a marketing disadvantage for the 'honest' manufacturers. Not least, there is a risk that the minimum lifespan would limit the freedom of the market, or that a form of planned obsolescence would be introduced. There is little incentive for manufacturers to design their products so that they would exceed the minimum lifespan imposed by the government. And consumers could be led to replace appliances at the end of the minimum lifespan even though they were still working.
S 1.3: Development of testing methods and standards for reviewing the life-time testing of components and devices	
Brief description	For many products and components there are not yet any generally available methods and standards for testing the lifespan. But these have to be developed in order to allow for independent testing (see Strategy 1.2). This would be helpful in particular for the retailers and smaller manufacturers, because establishing such test methods and standards requires considerable expertise.
Instrument	Standardisation, e.g. standards for material efficiency in accordance with the EU Eco-design Directive
Pro	Test methods could result in more tests with greater relevance. In particular, traders could demand that products satisfy a specific lifespan test.
Contra	Test methods can only partly reflect the real use of the appliance or components. For some products (e.g. washing machines, televisions) such testing might only make sense over longer periods in order to ensure more relevance.
S 1.4: Investigation of the influence of real-life use conditions on life-time and establishment of a standard with critical test conditions	
Brief description	Investigation of the influence of real-life use conditions on the life-time and establishment of a standard with critical test conditions. In particular, exposure to high temperatures and supply voltage peaks should be taken into consideration. The standard should specify what peak burdens are to be expected for the various appliances. This standard can then be used by manufacturers as a basis for carrying out lifespan testing under realistic use conditions.

[105] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of eco-design requirements for energy-related products

Strategy 1: Life-time requirements, standardisation, standards definition	
Instrument	Standardisation, e.g. a requirement for standards of material efficiency under the EU Eco-design Directive. However, there is still a considerable need for research, with detailed surveys of real use behaviour.
Pro	Where there may be marked deviations between real and nominal conditions it is important that manufacturers and test institutes base their tests on the real conditions and not the nominal ones.
Contra	Not enough is known about use conditions, or manufacturers do not know enough. Determining the real conditions of use initially requires extensive consumer surveys. The findings would have be subjected to a review after some years. Tests under extreme conditions involve higher costs and are therefore avoided in many cases.
S 1.5: Design for longevity	
Brief description	Measures for the design for durability include minimum quality standards for critical wear parts (see Strategy 1.2), repair-friendly design, availability of spare parts (see Strategies 3.1 to 3.3) and in selected cases modular designs (update and upgrade capability). For battery-powered appliances, e.g. laptops, the following requirements would seem appropriate as a minimum: (1) Specifications for the quality of batteries (charging cycles and cycle stability), see JRC 2014b; (2) Charging limits should be adjustable (e.g. implementation via the ACPI[106]), Default setting (e.g. 80% upper charging limit, 20% lower charging limit for Li-Ion batteries, irrespective of user behaviour); (3) Power management should avoid short recharging cycles that reduce the battery life; (4) Better information about optimum charging behaviour (e.g. in the operating instruction[107]); (5) Batteries that can easily be removed and exchanged by end consumers (or cost-efficient exchange by a repairer in the case of integrated batteries, included in the battery price; see Strategy 3.4). For televisions, for example, minimum requirements could be set for robustness, quality and durability under extreme and realistic use conditions [e.g. vibration test for transport simulation in accordance with MIL-STD-810G, Test Method 514.6 or Drop test in accordance with IEC 60068, Part 2: Ec (Freefall, Procedure 1) or EN 60384-4:2014-01 for high-grade capacitors]. Or minimum requirements for robust design in accordance with WRAP (2011a), e.g. requirements for the positioning of vulnerable components, such as sockets, on-off switch, function switches, etc., protection of the display unit, and the construction of the TV stand. The measures could also include the introduction of obligatory quality standards for the suppliers of components and parts, also covering the storage, transport and manufacturing (e.g. soldering processes) of components known to be susceptible to failure (e.g. aluminium electrolyte capacitors, main boards). Accompanying these measures, companies and public bodies should specify extended amortisation periods for purchases.
Instrument	This measure can be implemented as a minimum requirement in accordance with the EU Eco-design Directive and rules for purchases by public administrations. In connection with the obligatory quality standards for the suppliers, there is a need for research on the implementation and testing of such standards along the supply chain.
Pro	With specific measures regarding the length of life, all the environmental impacts related to the life-cycle, including resource consumption, would be placed in a real context. This strategy goes further than the former focus on energy consumption in

[106] Advanced Configuration and Power Interface (ACPI)

[107] A list of proposals for a simple and transparent implementation is provided by ifixit.com (https://de.ifixit.com/Wiki/Extend_Laptop%E2%80%99s_Battery_Life)

Strategy 1: Life-time requirements, standardisation, standards definition	
	the use phase. The legal framework can be provided through the EU Eco-design Directive. Currently there is an incentive in the form of a standardisation requirement for material efficiency under the EU Eco-design Directive.
Contra	All requirements of the EU Eco-design Directive and purchases by public administrations would have to be monitored. Since the market control bodies (and the public administrations) already face considerable challenges, the examination of the criteria called for here would be no trivial matter. If there is no systematic examination this would lead to clear market disadvantages for the ‘honest’ manufacturers. Testing the durability of components may in certain cases be costly and very time-consuming. The resultant delays would make market supervision ineffective in the interim. Overall, this could impede fair competition. Uniform standards should be developed for measuring the recharging cycles for batteries, so that the manufacturers’ statements can be compared.
S 1.6: Additional testing of lifespans by independent test institutes, such as Stiftung Warentest	
Brief description	The tests of Stiftung Warentest (StiWa) are regarded as a guarantee – at least in Germany – for the establishment of a minimum lifespan for washing machines of approx. 10 years of average use. This should be extended to other household appliances and technical appliances with long lives. However, such tests are expensive and cannot be financed solely by independent test institutes.
Instrument	Promotion of independent product tests
Pro	Seems a suitable possibility to influence the market in a targeted manner and to move it rapidly towards longer product lifespans.
Contra	The constraints on the general feasibility of test standards and the time taken for the testing also apply here (cf. Contra, S 1.5).

Table 107 Strategy 2: Minimum requirements for software

Strategy 2: Minimum requirements for software	
S 2.1: Development of innovative and modular software solutions	
Brief description	Development of innovative and modular software solutions separately from the hardware (so-called horizontal separation), so that these solutions can be used for successive hardware generations. This includes scalable memory for the integration of additional software, modular and portable software, regular up-dating of the software, provision of decoder solutions, etc.
Instrument	Further research and testing needed. These proposals should be developed further in a government-funded pilot-project in cooperation with specialist small or medium-sized software enterprises.
Pro	New functions and demands on the hardware do not lead to the end of the period of use of the product.
Contra	The regular software updating could prove costly; lack of experience in the sector regarding the development of such software solutions; no political instruments available to address software problems or to influence the software environment.
S 2.2: Essential software drivers must be kept available and updated for a sufficiently long period	

Strategy 2: Minimum requirements for software	
Brief description	The provision of driver updates should be binding for a certain period and when the driver support ceases it should be obligatory to release the source code for use by free developers (see also S 2.3). A process of certification of drivers must be developed, because otherwise there is a risk that malware could be introduced to the appliances. Another option is that the drivers would no longer be provided by the manufacturer but by a sub-contractor, who would make new developments available to the users after the end of the manufacturer's support.
Instrument	Further testing and research is needed, including about legal instruments.
Pro	The accustomed range of functions are still available, the appliances can be used longer.
Contra	Increased costs of driver support, existing software copyright law might have to be amended.
S 2.3: Promotion of free-standing software and hardware initiatives and creation of legal framework for their use and commercialisation	
Brief description	Open source operating systems could close the (software) gaps, because there are numerous derivates that are able to run on less powerful and older computers but which offer all the usual functions. With regard to drivers for free operating systems, if manufacturers are unwilling to release the hardware specifications, even for older appliances, then the community would have to develop suitable drivers by reverse engineering[108]. Such software products are in a legal grey zone under existing software copyright law and often cannot be marketed.
Instrument	Further testing and research are needed, including about possible political and legal instruments.
Pro	(Older) devices can be operated with open source systems; the accustomed range of functions are still available.
Contra	The companies have no economic stimulus to publish older hardware specifications and the existing property rights law may also present obstacles.
S 2.4 Compulsory hardware and software updates and full functionality tests	
Brief description	Obligatory hardware updates for an existing appliance; obligatory decoder solutions for reading the new formats. Provision of software updates via the Internet or clear customer information about how software should be updated in the event of poor or lacking Internet connection (e.g. via USB). If appropriate, 100% tests of all functions and appliances in the production as a requirement for the manufacturers. For reasons of data protection, an update process should clearly show how customer data is being collected, how it is being used, and who it is made available to. It should be considered whether an update process could be made available which required no data at all from the customers (e.g. which could also be carried out offline), so that the conditions of use would be unproblematic.
Instrument	This strategy could be implemented through the EU Eco-design Directive. However, data protection considerations should be considered carefully. Strict guidelines should be developed for the collection and use of customer data.[109]

108 Also called back engineering: extracting knowledge or design details from software in order to reproduce it.

109 See Ranking Digital Rights, an initiative to evaluate how IT companies deal with issues such as IT-security, data protection and freedom of speech (https://rankingdigitalrights.org/).

Strategy 2: Minimum requirements for software	
Pro	Framework conditions for regular updates have already been established and many manufacturers already offer this service.
Contra	Software or firmware updates are possible in many cases, but the inadequate bandwidth of existing hardware chips (transmitter and receiver chips) in the case of TVs, for example, leads to a loss of quality of Ultra HD presentations. Many TVs still only meet the Full-HD standard and do not have the decoder solution. Furthermore, in some cases, consumers reject the software update process and/or do not accept the update conditions, e.g. due to data protection considerations. In some regions, updates cannot be downloaded because of poor Internet connections. 100% function tests are time-consuming and expensive.
S 2.5: Standardisation, fault diagnostics function and new software solutions	
Brief description	Minimum requirements for the removal of constraints on a further use of the appliances, e.g. amendment of the conditional access of TVs with specifications about the availability of an appropriate slot[110]. Fault diagnosis and fault analysis functions should be directly available as a read out for the end-user. Standardisation of transmission standards and dynamic channel administration in the television sector should be promoted.
Instrument	This strategy could be implemented through the EU Eco-design Directive and/or the voluntary Type I environmental label.
Pro	There are no technical problems posed by the conversion of the conditional access and making direct fault diagnosis function/fault analysis available to the customers.
Contra	High costs for the development of new software solutions. Experts say that some 70% of the development costs for a TV set are due to the software. The TV market is changing rapidly (changing networks, new services, new interfaces), so that the TV manufacturer only has a limited scope of influence and other actors must also be included in the standardisation debate, e.g. network providers.

Table 108 Strategy 3: Reparability

Strategy 3: Reparability	
S 3.1: Improved framework conditions for independent and free-standing repair companies, including transparent repair information	
Brief description	Manufacturers supply spare parts to independent parts dealers; detailed repair instructions, including tools, diagnosis tools and information are provided for independent repair operators parallel to the product launch. With regard to the applications for the products considered here, it is particularly relevant that in the automotive sector there are legal requirements (Regulation No. 566/2011111) for manufacturers to make spare parts and diagnosis tools available to independent repair companies. This obligation was established by the EU Commission with the intention of limiting the market dominance of vehicle manufacturers and maintaining competition in the automotive maintenance sector. Diagnosis tools and

[110] See Section 6.2.2 for details

[111] COMMISSION REGULATION (EU) No 566/2011 of 8 June 2011 amending Regulation (EC) No 715/2007 of the European Parliament and of the Council and Commission Regulation (EC) No 692/2008 as regards access to vehicle repair and maintenance information

Strategy 3: Reparability	
	detailed repair instructions are usually made available for a basic charge (Ökopol GmbH 2015).
Instrument	This strategy could be implemented through the EU Eco-design Directive or a future directive for electrical and electronic appliances (analogous to Regulation (EU) No 566/2011 for vehicles).
Pro	Possibly lower repair costs for the end customer. Preserves jobs in specialist dealers and repair businesses, offering close contacts with customers by local specialist dealers.
Contra	Questions of patents and investment rights remain to be clarified. The use of repair instructions by independent repair companies could lead to warranty issues if safety-relevant functions are affected. This issue requires further detailed investigation. It is uncertain how easily experience can be transferred from the road vehicle sector. “The importance of repairs for road vehicles is primarily related to the very high price of the product. A car is typically by far the most expensive purchase a consumer makes, with the exception of property. In view of the purchase price, it is therefore worth carrying out many repairs” (Ökopol GmbH 2015).
S 3.2: Mandatory specifications for maintaining availability of spare parts, including transparent information concerning anticipated costs of spare parts	
Brief description	Clear minimum requirements for the storage of spare parts and tools required for a successful repair. Spare parts should remain available for a minimum period after production, depending on the product group or the price of the appliance. For example, for 5 years in the case of a product costing up to € 500, or for 10 years if the price is more than € 500. Furthermore, a limit could be set for the cost of a spare part as a maximum proportion of the price of the new appliance (e.g. not more than 20% of the full price). A market could also be created for third-party components. This would involve making documentation available (e.g. about interfaces) and the introduction of standardisation as well as obligatory licensing, so that it would be possible for a third-party manufacturer to produce parts.
Instrument	This strategy could be implemented through the EU Eco-design Directive or a future directive for electrical and electronic appliances (by analogy with the EU Regulation 566/2011 on access to vehicle repair and maintenance information). More research is needed on how the proposed model could work in practice. Above all it is necessary to examine possible economic and environmental effects.
Pro	This binding minimum requirement could also establish an obligation to provide information about the availability of spare parts, analogous to the current French legislation (Code de la consommation, Version consolidée au 22 mars 2015, Art. L111-3).
Contra	Prices for new appliances are falling, so that even if prices for spare parts are limited in advance, it can be economically more attractive to buy a new product than to replace a part in order to continue using the old appliance. This measure would impinge on the freedom of a company to make innovations. Some innovations, e.g. higher-efficiency motors, etc., would be sensible solutions from an environmental point of view, but would certainly be expensive as replacement parts. A portion of the high costs for spare parts would be included in the purchase price in order to circumvent such a measure. Manufacturers might increasingly attempt to secure their position by claiming intellectual property rights and charging high prices for licences.

Strategy 3: Reparability	
	The economic and environmental effects of such a regulation would have to be investigated in greater detail.
S 3.3: Batteries and other wear parts must be easy to replace or repair	
Brief description	It should be possible for the user to replace or repair wear parts and batteries declared by the manufacturers or to have this work carried out inexpensively by a repairer. It is important that non-destructive disassembly of appliances is possible for repair purposes.
Instrument	This strategy could be implemented as part of the EU Eco-design Directive or through a future directive for electrical and electronic appliances (analogous to Regulation (EU) No 566/2011 for vehicles).
Pro	Increases market transparency and returns control of the appliance to the user.
Contra	None
S 3.4: Changes to the cost calculations for repairs	
Brief description	This involves developing new ways of dealing with high repair costs. For example: (1) Repair costs should not include any call-out charge, i.e. the costs for a call-out should form part of the purchase price; (2) Changes should be made to the way charges are calculated, e.g. a repair should always cost the same, whatever the price of the replaced part. This would eliminate uncertainty about the repairs arising while the product is being used; (3) Information about the expected costs of a repair would have to be provided in the product documentation or on the Internet, (e.g. the costs of the various parts and components and the average flat-rate call-out charge), see also Strategy 3.2. In principle, the possible repair costs should be internalised as far as possible and the real costs for consumers should be made more apparent when a product is purchased. The implementation of the model should be combined with an appropriate integration of the independent repairers.
Instrument	More research is required on how the models proposed here would work in real life. The information about expected repair costs could be provided through the EU Eco-design Directive or by means of a future directive for the repair of electrical and electronic appliances (like the Regulation (EU) No 566/2011 for vehicles). There is also a need to examine the possible effects of this measure on independent repair businesses if they are not integrated in an appropriate manner.
Pro	The real costs (for acquisition and repairs) will be made more transparent for the customers.
Contra	Concerning (1): If call-out charges are included in the purchase price, the overall costs are the same in the end. Consumers will have to pay more initially, and those who do not require any repairs will bear some of the costs for the others. Concerning (2): Such a measure would make simple repairs more expensive and reduce the cost of repairing complex parts and components. The prices for repairs and for spare parts change every year, but the product documents specify the repair costs at the time of purchase. A major risk of this measure is that the independent repair companies could be put out of business if they are not fully integrated in an appropriate manner.

Table 109 Strategy 4: Servicing models of manufacturers for extending lifespan and use time

Strategy 4: Servicing models of manufacturers for extending lifespan and use time	
S 4.1: Leasing models (as an alternative to ownership)	
Brief description	Manufacturers/dealers retain ownership of the products but allow the consumers to use them. In other words, the service or function is leased instead of the product being purchased. Manufacturers/dealers can also provide a maintenance and repair service as part of this model.
Instrument	Formulation of a corresponding contract with a suitable distribution of risks and liabilities within the scope of the German Civil Code (BGB). This recommendation will have to be subjected to in-depth legal scrutiny (see also Schlacke et al. 2012).
Pro	Strong ties develop between customer and retailer. Leasing means that the customers will not have to invest the full purchase price in advance. This supports the sales of more expensive products with longer lifespans. The period of use can be extended by maintenance and upgrades and updates of the hardware and/or software. Manufacturers can learn from the returned products about the actual user behaviour and the period of use, and can gain insights for the targeted development of new appliances.
Contra	High costs for the administration of the leasing contracts – therefore only feasible for expensive appliances. Leasing companies commit large amounts of capital, and the resultant costs have to be borne by the customers in the final analysis. Thus, this option is much more expensive than a private acquisition. Leasing only has a direct feedback effect on the design if the leasing partner is also the manufacturer. Investigations have shown that alternatives to ownership do not necessarily offer environmental advantages. For example, more intensive use can lead to increased wear, particularly if the user is not the owner of the product and may therefore handle it negligently (see Schlacke et al. 2012). Leasing agreements that offer to exchange the product at regular intervals can lead to newer products flooding the market, considerably reducing the period of use of older products.
S 4.2: Buy-back agreement	
Brief description	The product will be taken back by the manufacturer/dealer and prepared for re-use. This measure would make it possible to use the products over their entire lifespan (with a series of consumers) and to avoid the premature disposal of the product. The terms and conditions should be formulated so as to ensure that the period of use is as long as possible. This approach also offers the opportunity to retrieve valuable parts and components from the old appliances for re-use. Promotion of re-use and the second-hand market by establishing an umbrella brand for quality (e.g. professionalisation of the second-hand market for ICT appliances, including secure management of data deletion).
Instrument	Formulation of a corresponding contract with a suitable distribution of risks and liabilities within the scope of the German Civil Code (BGB). This recommendation requires detailed scrutiny of the legal implications.
Pro	The rate of return of products would be much higher than at present. The returned appliance would offer considerable potential for the re-use of spare parts from the returned appliances.
Contra	High administrative costs, therefore only feasible for expensive products. It is uncertain how attractive the used appliance sector would be for ICT devices and consumer electronics in view of the rate of innovations and market dynamics.

Strategy 4: Servicing models of manufacturers for extending lifespan and use time	
	In the worst case, the measure could be integrated in a strategy to promote new sales if the period of use of the individual customers is limited.
S 4.3: Aftercare as a service	
Brief description	The product lifespan and period of use is extended by the manufacturers and retailers offer the follow-up care as a service (e.g. by improving the availability of parts for maintenance and repairs). The measure could take a variety of forms, e.g. the retail price could include a certain number of repairs over a specified period, and the provision of replacement parts, or expansion of repair services in cooperation with the retail chains, and/or in partnership with accredited repair companies.
Instrument	Voluntary offers by manufacturers
Pro	The maintenance of appliances would become an interesting business model.
Contra	For some companies this could mean the end of their current business model, because they will not be able to calculate the risks, or the risks may seem too large. For the customers there is a lack of distinction between product and service costs.

Table 110 Strategy 5: Information obligations, consumer information

Strategy 5: Information obligations, consumer information	
S 5.1: Clear declaration of breaking points [112], wear parts and maintenance intervals	
Brief description	Breaking points and wear parts should be recognisable for consumers, and the conditions should be made clear under which the breaking points and wear parts will fail, or when maintenance should be carried out (time intervals, use cycles or limit values). This also includes information about constraints on use, e.g. only short periods of use for hand mixers. For example, the problem of blocked air vents of a laptop could be tackled with an automated sensor (e.g. a temperature sensor, or after a specified period or number of use cycles), with an electronic signal indicating the need for maintenance. In addition, it should be possible for the users to carry out maintenance themselves, for cost reasons.
Instrument	This measure could be implemented under the EU Eco-design Directive and/or the voluntary Type I Environmental Label.
Pro	Increases the market transparency for consumers.
Contra	It is necessary to test whether and under what circumstances this may come into conflict with commercial secrets. Increased efforts may be required to determine and specify breaking points and wear parts for various product groups.
S 5.2: Consumer information on extending use periods	
Brief description	A series of measures that address the topic of product life and use duration, e.g. communication of the environmental impact of short-lived products, notification of life-cycle costs (LCC), resource consumption, etc.

[112] A breaking point is designed to fail under a certain load or after a certain period in a planned manner in order either to minimise further possible damage to the entire system or to achieve some other special objective. This is not to be confused with a weak point, which refers to a mechanical or electrical element that is particularly liable to fail and thus curtail the lifespan of a product.

Strategy 5: Information obligations, consumer information	
Instrument	Consumer campaigns in Germany or Europe-wide
Pro	Such a campaign could be combined with extended requirements for the provision of information about lifespans by manufacturers and retailers.
Contra	Would have to be a long-term campaign with basic messages. It is not clear how various groups of consumers would react to the variety of information about product lifespan (e.g. details of lifespan, reparability, availability of spare parts, minimum guarantees, etc.) in combination with other parameters (e.g. prices, innovation cycles, demographic development, etc.), and which decisions they would then actually make in real purchasing situations.

9 Conclusions and prospects

This analysis of the trends for lifespans and residence times and the causes of obsolescence has shown that the investigated appliances were replaced for a wide range of reasons, involving highly complex combinations of material, functional, psychological, and economic obsolescence. Even the causes of material obsolescence are as a rule very diverse, which makes it difficult to reach any definitive conclusions.

However, the comprehensive analyses in this study confirm that the first-use period for most of the investigated product groups has decreased in recent years (e.g. large household appliances, TVs, and laptops). And more electrical and electronic appliances are being replaced although they are still in working order, with technological advances frequently acting as a stimulus, as in the case of televisions. A third of large household appliances were still working when a replacement was bought because the consumer wanted a better appliance.

On the other hand, it was also found that the proportion of large household appliances replaced because they had become defective within five years increased from 3.5 per cent of all purchases in 2004 to 8.3 per cent in 2012. This trend was confirmed by an investigation of washing machines received by recycling plants. An analysis of the production dates of washing machine capacitors showed that more than 10% of washing machines in 2013 were 5 years old or less (6% in 2004). A further online consumer survey also showed, among other things, that a considerable proportion of appliances (e.g. washing machines, TVs and laptops) are disposed of before 5 years of use.

A long period of use of electric and electronic equipment is important due to environmental considerations. Products with a long lifespan usually have a lower environmental impact and make better use of resources, provided that they are then actually used for a longer period and are not replaced prematurely. Many consumers replace appliances that are still working because they want the innovative functions and an improved image promised by new models. If products are designed to have a longer lifespan this mostly involves using higher-quality materials, while spare parts have to be manufactured and then stored over a number of years. In addition, the development requires costly and time-consuming durability testing. If products designed to have a long working life are replaced prematurely, then under certain circumstances this could have a negative environmental impact.

Therefore, the strategies against obsolescence must simultaneously adopt two main approaches, as summarised in **Fehler! Verweisquelle konnte nicht gefunden werden.**. These are considered in detail in Sections 9.1 and 9.2.

Table 111 Main approaches for the strategies against obsolescence

Approaches for strategies against obsolescence		Actors addressed	Strategy
1	Strategies to achieve min. lifespans and to extend useful product lives	Manufacturers Policy makers (standardisation)	Strategy 1: Lifespan specifications, standards
2	Strategies to extend the useful product life	Manufacturers Policy-makers (better conditions for the repair sector) Consumers (behaviour)	Strategy 2: Minimum requirements for software Strategy 3: Reparability Strategy 4: Service models of the manufacturers for extended lifespan and useful lives

Approaches for strategies against obsolescence	Actors addressed	Strategy
		Strategy 5: Disclosure of information, Consumer information

9.1 Strategies to achieve an ensured minimum lifespan and extended useful product lives

In view of technological advances and innovations made with electrical and electronic appliances it is questionable whether highly specific individual design demands on products are promising or even if they make sense. It would seem much more important to introduce *minimum requirements for product lifespan and quality* irrespective of product design and the product group. And in view of the fact that in many cases it is economic obsolescence that leads or can lead to the end of the useful life of a product (see Sections 6.2.4, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**), the right objective would seem to be a reliable product lifespan within which repairs are only required in rare cases if at all.

In order to develop such minimum requirements and to be able to test them reliably it is necessary to establish *industrial standards*. There are already a range of standards and codes of practice for the safety and fitness for use of parts of electrical and electronic appliances (*see Annex IV and Annex V*). However, what is lacking in the opinion of the experts surveyed is *"… lifetime-related testing of products, not just of individual parts. In the safety standards for household appliances requirements and tests are specified for individual components and parts regarding quality and durability, but the focus is always on safety and avoiding dangerous situations, rather than considering the functioning of an appliance. Possibly it might be sufficient for some appliances, to specify quality requirements for the critical parts rather than testing the appliance as a whole".* For example, applying the standard EN 62506 "Methods for product accelerated testing" could help to shorten the lifespan tests, which otherwise can take a very long time.

It is possible to develop further suitable test standards, but this requires the active involvement of many experts, with appropriate measures to ensure repeatability and reproducibility, e.g. in accordance with DIN SPEC 40619. According to experts, producing a new standard would take 30 to 60 months. Nevertheless, the national and international standards organisations (DIN, DKE, CENELEC, IEC) should work to develop relevant measurement standards with which the lifespans of electrical and electronic products could be tested realistically.

On the other hand, existing *standards for components of electrical and electronic appliances* represent a possible starting point, even though they were primarily intended for testing safety and functionality. This has been shown by a study of the European Commission on product durability (see Boulos et al. 2015).

According to Boulos et al. (2015), safety standards could also include aspects relating to durability. Product safety could also be maintained or improved if defects occurred only rarely or not at all, particularly for electrical and electronic components. A more durable product may reduce the probability of safety risks by reducing the probability of failures. Safety and durability standards therefore have some common objectives, so that the test methods for both aspects could be similar (Boulos et al. 2015).

For this reason, it is recommended that existing safety standards at the component level should be examined for their suitability for lifespan and durability testing, and that suitable adaptations be made if appropriate. The initial focus could be placed on components and parts that are more liable to develop defects or wear out. Boulos et al. (2015) show for refrigerators and cookers that this can be more cost-effective and less time consuming than development of completely new standards at the level of the products.

However, it is important that the appliances are designed in accordance with the *realistic range of conditions* in which they will be used. Otherwise the result can easily be that demands are placed on the appliances that lead to them becoming defective prematurely. Limitations on the use of an appliance, for example only short periods of use, should therefore be clearly stated on the packaging and on the appliance itself. Special installation conditions should also be clearly specified. In order to be able to take these factors into account, the product developers and designers must be aware of the conditions under which the appliance will subsequently be used. This can be achieved by *integrating users in the product development process*. The result would provide a basis on which clear requirements could be specified between suppliers and dealers. In an increasingly globalised world of goods, such trading norms would certainly be advantageous. More research is needed to establish the real range of conditions under which appliances are used. For example, this can apply for power supplies, which because of the increasing integration of energy from alternative sources are facing growing challenges to maintain stability.

For all these reasons, the *lifespan requirements and standardisation* form the core of general strategies against obsolescence.

9.2 Strategies to extend the useful life of products

In Section **Fehler! Verweisquelle konnte nicht gefunden werden.**, it was shown for washing machines, laptops, and televisions that appliance with longer useful lives are much superior than shorter-lived ones from an environmental point of view. In addition to strategies to extend the product lifespan, or to ensure a minimum lifespan (see previous section), measures and models are also relevant that serve to extend the *useful life* of products. In the worst case, products with a longer life may be less favourable from an environmental point of view when full use is not made of the technically possible lifespan, for example for reasons of functional and psychological obsolescence. An important measure in this context could be to introduce a requirement for a *minimum useful life of electrical and electronic equipment purchased by public administrations*, firstly because of their influences as large-scale purchasers, and secondly because they could act as a model for other public and private purchasers (Prakash et al. 2016). This would involve extending the relatively short periods of use of appliances in the regulations for German public administrations[113].

In addition, *innovative services* provided by manufacturers (e.g. leasing, product buy back agreements, or acceptance of returned goods after use) as well as obligatory *minimum requirements for software*[114] can contribute to ensuring that the technical product lifespan can

[113] Cf. regulations for IT hardware and software were published by the German Federal IT Office, No. 2013/7, 6 December 2013; http://www.cio.bund.de/SharedDocs/Publikationen/DE/Bundesbeauftragter-fuer-Informationstechnik/IT_Rat_Beschluesse/beschluss_07_2013_download.pdf?__blob=publicationFile; Accessed: 06.10.2015

[114] UBA has commissioned a project on Sustainable Software Design (*FKZ 3715 37 601 0)* with the remit to develop criteria for investigating the environmental impact of software, possibly as a basis for awarding an environmental label. Guidance will be formulated for energy- and resource-efficient software development. Contractors: Oeko-Institut e.V., Hochschule Trier and University of Zürich.

actually be achieved (e.g. by upgrading for further use or second use, guaranteed repairs by the manufacturer, or improved coordination of software and hardware solutions). In addition, the various service models could potentially have a positive influence on the market for higher-quality products with longer lives. However, further work is needed to remove certain demand-side and supply-side constraints before such a business model would work (Roedig 2015).

Measures to *improve consumer information* (e.g. about the environmental advantages of products with a long lifespan) and to *oblige manufacturers to provide information* (e.g. explicit declaration of wearing parts) are further important instruments to influence buyers to choose more durable products. Further research is needed on how various consumer milieus react to information about product lifespans[115] (e.g. lifespan information, reparability, availability of spare parts, minimum warranties, etc.) and the decisions actually reached in interaction with other parameters such as prices, innovation cycles, or demographic development in real purchasing situations. Some consumers wanted more detailed product information, whereas others felt overwhelmed by excessive amounts of information. A comprehensive analysis of consumer behaviour is needed in order to establish the effect of complex consumer information in comparison with other strategies.

From an environmental point of view, it is also important that appliances can be repaired in order to extend the useful life. For some years now, there has been an intensive debate on this topic in Europe, especially concerning improvements to the situation for independent repair shops and specialist dealers. The analysis of economic obsolescence (see Sections 6.2.4, **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.**) showed that the costs for spare parts and labour in comparison to the falling prices of new products often reduced to willingness to have repairs carried out. In addition, increasing product complexity and the highly integrated nature of modern products, as well as remote software-based error diagnosis and debugging represent considerable challenges for independent repair businesses. The social effects on the independent repair sector of modern product development in the sector of electrical and electronic products seem at present to be uncertain.[116]

A *strategy for improved reparability* could, among other things, create conditions for maintaining the independent repair community in Europe. However, it is necessary to examine the prospects of such a strategy in the light of the challenges outlined above. The interactions of market developments and consumer-behaviour with regard to electrical and electronic appliances with the socio-economic development in the repair sector in Germany should be investigated.

From an environmental point of view, whether a chosen repair service is independent or toed to a specific manufacturer is less relevant. It is important that repairs are possible and that the consumer makes use of this option (Strategy 4). Even more important, however, is compliance with minimum quality standards and reliable lifespan testing for the products (Strategy 1), so that repairs are only rarely required if at all.

[115] A UBA report on strengthening sustainable consumption examines the effectiveness of manufacturer guarantees (e.g. consumer-side effects, acceptance, etc.) (Schlacke et al. 2015).

[116] In an open letter (15 July 2015), the “MeinMacher-Netzwerk” network, consisting of some 1000 retail traders and repair workshops for electrical and electronic appliances in Germany, criticised the debate on a possible extension of warranty periods and stressed the difficult situation of the independent repair sector in Germany. They argue: “*If repairs are placed in the hands of the manufacturers, this will mean the end for most stationary retail traders and repair workshops in Germany. Many customers choose a specialist retailer because they not only offer helpful advice but can also be contacted personally in the event of a defect and can carry out repairs. For many specialist retailers, who are anyway finding it hard to compete with the mega-stores and discounters, this would not only mean the loss of an important selling proposition. It is also important to understand that repairs and services represent an essential economic support for them, because they cannot exist solely from trading margins. This would probably result in a grave loss of know-how, jobs, and training opportunities*”.

As explained in Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**, legal and economic instruments for extending the lifespan and the useful life of products are not considered in this report. Legal and economic instruments for extending product life and period of use are treated in detail in two other UBA projects. Currently, legal possibilities are being discussed in the civil society[117] that could influence the product development processes and the product communication. For example, *appropriately formulated warranty requirements* could mean that product developers would have to do much more to reduce the risk of early failures. From a technical point of view this would be highly advisable.

9.3 Strategies against obsolescence in the context of product development

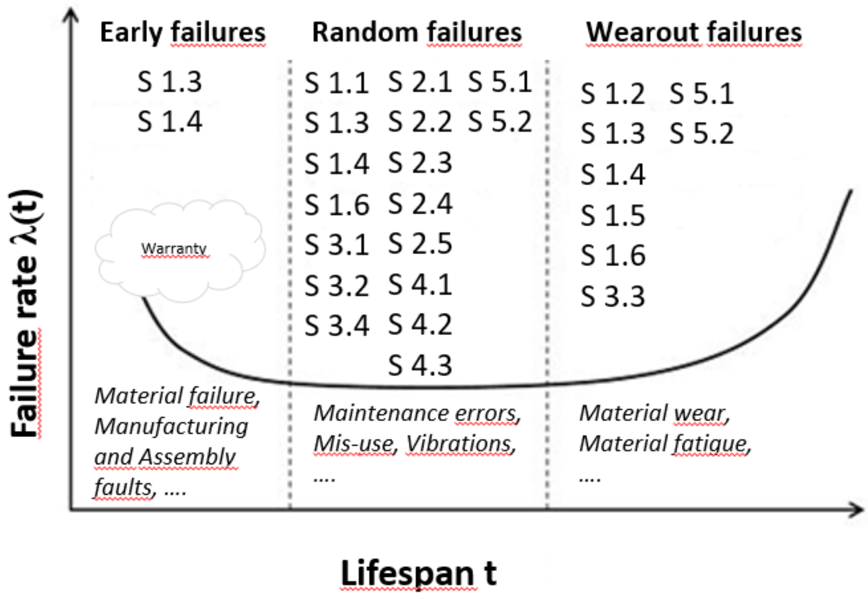
As already described in **Fehler! Verweisquelle konnte nicht gefunden werden.**, the failure rates of products vary in the course of the lifespan along the so-called "Bath tub curve". This involves a slightly increased failure rate in the first years ("Early failures") as a result of failures to materials, production or assembly, followed by lower levels of "Random failures" due to maintenance errors, inappropriate use, followed finally by ("Wear-out failures") at the end of the product lifespan as a result of material ageing, etc.

The strategies against obsolescence developed in Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** target different phases of the product lifespan and address different types of failure. This background has to be taken into consideration by political decision-makers so that they can better assess interventions and the relevant product policies to extend product lifespans and periods of use.

To show the possible applications of the strategies against obsolescence developed in the previous sections, in Figure 106 the individual measures are allocated to the various phases of the bath tub curve.

Figure 106 Strategies against obsolescence in the context of product development (bath tub curve)

[117] See BEUC (2015): Durable goods: More sustainable products, better consumer rights – Consumer expectations from the EU's resource efficiency and circular economy agenda



Source: Our presentation

Early failures are inacceptable for consumers and are also environmentally undesirable. They can be reduced by testing products under realistic and extreme conditions in accordance with appropriate standards and measurement regulations. Legal and economic instruments such as guarantees and warranty periods can also be effective, but these are outside the scope of this study.

Figure 106 shows that the majority of the proposed measures address the phase of *random failures*. These are caused by maintenance errors and inappropriate use during the characteristic period of use, or can be the result of mechanical impacts such as vibrations.

Most strategies to extend the lifespan and the period of use focus on the phase of random failures (e.g. with innovative service models) and the start of the phase of *wear-out failures* (e.g. by replacing worn-out parts and other repair measures). More stringent testing of lifespan, product quality and durability lead to a reduction in random failures and a delay in the start of the phase of wear-out failures.

9.4 Obsolescence = planned obsolescence?

Finally, it seems appropriate to comment on the public debate on obsolescence and planned obsolescence. In recent years media coverage of "planned obsolescence" has been very emotional and critics see society divided into two opposing camps:

1. Manufacturers are "perpetrators" who manipulate the design of their products to intentionally introduce weak points so that the products fail in a planned manner after a pre-defined period. This suggests that the manufacturers use this strategy to boost sales and force the consumers to make new purchases;
2. Consumers are "victims" of a conspiracy, because they had no way of combatting the manufacturers' strategy.

But this study has shown that obsolescence, i.e. the natural or artificial ageing of products, is not as one-dimensional as this.

Manufacturers and consumers interact with one another in a constantly changing setting, and both influence the product development and patterns of consumption. In the scientific community, it is accepted that the product lifespan is a plannable parameter which product developers use as an orientation. The design of a product lifespan is influenced by many factors, such as use patterns, wear reserves, maintenance, changing technology, trends, fashion and values, as well as external environmental influences. Ideally, the technical product lifespan would correspond to the period of use of the product. In order to realise the optimisation targets, all parts should be configured to have a comparable lifespan, for example in order to avoid incurring costs and deploying resources to create unnecessary wear reserves. The basic aim must be to design products to last as long as necessary, rather than as long as possible. Measures to “unnecessarily” extend the technical lifespan might even increase the demands on resources during the production process, which would be environmentally counterproductive.

The demands placed on products have to be seen in the context of the use parameters and the use setting. In other words, the decisions about product lifespan are oriented towards the objectives and the target groups of customers, as well as the scenarios for future developments of markets and technologies[118]. The demands therefore differ from product to product and from company to company. This is reflected in the retail prices of the products, which are also affected by other factors such as servicing provisions, the period for which spare parts will be available, additional uses, design, updates, reparability, and mechanical and electronic robustness. For example, a company marketing the long lifespan of its products as its USP will place very different demands on the product and its supplier management than a company targeting the low-price segment of this product category. The technical planning and design of products to provide an appropriate lifespan which takes environmental and economic considerations into account can therefore also be seen as “planned obsolescence”, but not in the sense of a manipulative influencing of lifespan by the manufacturers, as in the popular public discourse.

To this extent it is possible to confirm that there is “planned obsolescence”, because the planning and design of the product lifespan is an integral part of the product policies of companies. The more carefully the manufacturers carry out their lifespan tests and the closer they adapt their test conditions to real use conditions, then the greater the certainty with which they can make statements about the expected lifespan, the probability of a certain lifespan being achieved, or of certain parts failing at various times. On the other hand, against the background of shorter product cycles, falling product prices, it can be seen that costly and time-consuming lifespan tests have been cut back, and in some cases only the most important functions are tested. The result is that manufacturers themselves are unable to give any reliable information about the lifespan of their products.

It was not the aim of this study to confirm or discount the allegation that manufacturers intentionally design certain parts so that these will become defective after a certain period of time in order to make consumers buy a new product. Rather, the study aimed to analyse the average lifespan and use periods, and the reasons why products fail or are replaced.

The analysis has shown that there are in fact many reasons for replacing products, whether material, functional, economic or psychological. Even technical defects in products can have a variety of causes. It was not possible within the framework of this study to identify key factors, including any relating to the intentional introduction of weak points.

[118] However, the lack of transparency about these criteria means that consumers are unable to make optimum purchasing decisions (asymmetric information).

9.5 Prospects

The strategies against obsolescence proposed in this study aim to eliminate the information asymmetries between manufacturers and consumers about the anticipated product lifespans and the intensity of use envisaged by the manufacturer. The recommended strategies would make it the responsibility in particular of the manufacturers and policy-makers to provide increased transparency about the expected lifespan of products and to specify quality requirements for products, parts and components. On the other hand, consumers should use the products for as long as possible in the interests of environmental protection and resource conservation.

In order to implement the recommendations outlined in this study, further research will be required in the following sectors:

- **Lifespan requirements, standardisation**
  - Testing and adaptation of the existing safety standards at the component level (focussing on components that are liable to break or wear out) with regard to their suitability for lifespan and durability testing.
  - Generating knowledge about the real conditions of use and impacts on products with comprehensive surveying of consumers and a subsequent investigation of the influence of real use conditions (e.g. thermal burdens and peak power supplies) on the product lifespan.
- **Software**
  - Development of innovative and modular software solutions for extending product lives and useful lives in a pilot project in cooperation with specialist small and medium-sized software companies.
  - Cost/benefit analysis and risk assessment for measures relating to software updates, the provision of software drivers for a number of years and the promotion of free software and hardware initiatives.
- **Repairs**
  - Cost/benefit analysis for an EU directive for electrics and electronic appliances (analogous to Commission Regulation (EU) No. 566/2011).
  - Influence of modern product developments and consumer behaviour with regard to electrical and electronic products on the independent repair sector in Germany, including a future analysis and the development of a timetable for the repair requirements in the field of electrical and electronic products.
  - A comprehensive and product group specific life-cycle analysis and a cost/benefit analysis of the proposals made in connection with reparability, e.g. modularity and replaceability of components and requirements for the obligatory stocking of spare parts, taking real use behaviour into consideration.

► **Consumer behaviour**

- Analysis of the real consumer behaviour with regard to purchasing decisions for or against long-lived products against the background of available product information, e.g. lifespan information, reparability, availability of spare parts, minimum warranties etc.) and other factors such as prices, innovation cycles, demographic development, etc.

► **Service models of the manufacturer**

- Testing of legal options and the promotion of service models, such as leasing and buy-back provisions in the private sector.

Strategies against obsolescence cannot be implemented from one day to the next. Rather they should be regarded as a societal task to be tackles in combination between policy-makers, manufacturers, scientists, and consumers.

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A Appendix

A.1 Questionnaire for the product group “Televisions”

Influence of period of use of products on their environmental impact: Creating an information base for the development of strategies against obsolescence (*original in German*)

Questionnaire: Television

1. The causes of obsolescence

1.1 How would you estimate the likelihood of failure of the following components / parts?

	Likelihood of failure			
Component	**Never**	**Rarely**	**Often**	**Very Often**
Housing				
Switches				
Interfaces / connections				
Stand				
Display / Monitor unit				
Plug connections				
Al-electrolytic capacitors				
Soldering				
Power supply card				
Main PCB				
Loudspeaker				
Screws				
Others: ____________________				

1.2 What are the reasons for the failure of components that fail frequently or very frequently?

1.3 Does the failure of these components mean the end of the lifespan of a television?

☐ yes	☐no

1.4 If no, which of the above-mentioned components can be repaired or replaced?

1.5 What would such a repair cost?

Component	Labour costs	Cost of parts	Time taken for repair
Housing			
Switches			
Interfaces / Connections			
Stand			
Display			
Plug connectors			
Al-electrolytic capacitors			
Solder connections			
Power supply card			
Main PCB			
Loudspeaker			
Screws			
Others: ____________________			

1.6 What technical measures could work against the causes mentioned above?

1.7 What obstacles are in the way of implementing such technical measures?

1.8 Which of the above-mentioned components / parts could already be up-graded during design and development so that the appliance could be used longer without relevant cost increases (<5% of overall costs)?

2 **Questions about lifespan** (Technical obsolescence = Qualitative (i.e. material) deficits shorten the useful life of appliances)

Definitions:

- *The technical **lifespan** is the average time from the first marketing to the terminal defect of the appliance.*
- *The **period of use** is how long an appliance is used for its intended purpose. This includes use by subsequent holders after the appliance has been given away or sold.*
- *The **residence time** is the time from the purchase of an appliance until its collection for disposal.*

2.1 How is the lifespan of a television determined? Please describe the relevant methods or attach these to the questionnaire.

2.2 What specifications do you make for your suppliers about the lifespan / period of use / frequency of use? How do you check compliance?

2.3 We assume that higher quality components and parts have a longer lifespan. How do these differ from lower-quality components or parts that fail frequently/very frequently?

Differences				
Material [Type, description]	Price [euros]	Availability [years]	Design [reparability, etc.]	Development and testing times

2.4 What do you take into account concerning the specification for the lifespan...

2.4.1 …in the design process for the mechanical components that fail frequently/very frequently?

2.4.2 …in the design process for the electric components that fail frequently/very frequently?

2.4.3 …in the approval process for the mechanical and electric components that fail frequently/very frequently?

2.4.4 … in the certification process for the mechanical and electric components that fail frequently/very frequently?

2.5 Please give examples of how you would design a television with a short lifespan and one with a long lifespan.

2.6 Which components are key when designing a television that is as durable as possible?

2.7 What strategies do you adopt to reduce the failure rate of electric and electronic appliances?

3 Questions about functional obsolescence

(Functional changes of appliances shorten their useful life)

3.1 How do functional factors (e.g. software updates, etc.) affect the lifespan and the period of use of a television?

3.2 What factors are liable to make consumers purchase a new television because they are dissatisfied with the functionality of the one they own? How are these factors taken into consideration during design/planning?

3.3 Does a close link between operating system and hardware mean that the lifespan of the software necessarily determines the lifespan of the hardware? Please give an example for televisions.

4 Breaking points

A breaking point is designed to fail under a certain load or after a certain period in a planned manner in order either to minimise further possible damage to the entire system or to achieve some other special objective.

4.1 Are breaking points included in the design of televisions and which technical, safety-related or legal requirements must they meet?

4.2 How are breaking points chosen for an optimum period of use of the appliance?

Thank you for taking part!

A.2 Overview of institutions contacted[119]

No.	Institution	Topic
1	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway	Power supplies
2	TU-Dresden, Institut für Elektrische Energieversorgung und Hochspannungstechnik	Power supplies
3	Deutsches Zentrum für Luft- und Raumfahrt (DLR)	Ionising radiation
4	VDE Prüf- und Zertifizierungsinstitut	Test institute
5	TÜV-Rheinland	Test institute
6	SLG Prüf- und Zertifizierung GmbH	Test institute
7	Stiftung Warentest	Test institute
8	Institut für Markt-Umwelt-Gesellschaft (imug)	Consumers/psychology
9	Institut für ökologische Wirtschaftsforschung (IÖW)	Consumers/psychology
10	Universität Oldenburg, Fakultät für Informatik, Wirtschafts- und Rechtswissenschaften	Consumers/psychology
11	TU-Dortmund, Wirtschafts- und Sozialwissenschaftliche Fakultät	Consumers/psychology
12	Verbraucherzentrale NRW (Umwelt)	Consumers/psychology
13	Verbraucherzentrale NRW (Recht)	Consumers/psychology
14	Verbraucherzentrale Bundesverband	Consumers/psychology
15	Wuppertal Institut für Klima, Umwelt, Energie GmbH	Consumers/psychology
16	Universität Potsdam, Lehrstuhl für Betriebswirtschaftslehre mit dem Schwerpunkt Marketing	Consumers/psychology
17	TU-Berlin, Institut für Berufliche Bildung und Arbeitslehre, Arbeitslehre/ Ökonomie und Nachhaltiger Konsum	Consumers/psychology
18	TU-München, TUM School of Management	Consumers/psychology
19	Aalborg University, Center for Design, Innovation and Sustainable Transitions	Consumers/psychology
20	Verbraucherzentrale Bundesverband	Consumers/psychology
21	Sustainable Design Centre (SDC)	Design
22	Rebeam, Recycling and Recommerce	repair
23	ReUse Computer	Repair
24	Repair- und Service-Zentrum (R.U.S.Z), Vienna	Repair
25	Reparaturnetzwerk Österreich	Repair
26	Recyclingbörse Herford	Repair

[119] Not all institutions replied, see Section 6.1.1

No.	Institution	Topic
27	ITRAC POS & DISPLAYS GmbH	Repair
28	Netzwerk Haushalt - Berufsverband der Haushaltsführenden	Civil society
29	Journalist (1)	Media
30	Journalist (2)	Media
31	Fachgemeinschaft für effiziente Energieanwendung	Civil society
32	Fraunhofer IWM	Material sciences
33	Deutsches Institut für Normung (DIN)	Standardisation
34	c't magazin für computertechnik	Media
35	Bundesanstalt für Materialforschung und –Prüfung (BAM)	Design
36	Deutsche Energieagentur (dena)	Civil society
37	Werkstatt Frankfurt	Repair
38	Dr. Brüning Engineering UG	Standardisation
39	AfB – Social and Green IT Europe	Repairs
40	Samsung Electronics GmbH (Haushaltsgeräte)	Manufacturer
41	Miele & Cie. KG	Manufacturer
42	Bauknecht Hausgeräte GmbH	Manufacturer
43	Electrolux Hausgeräte GmbH	Manufacturer
44	Robert Bosch Hausgeräte GmbH	Manufacturer
45	Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V. (BITKOM)	Industrial association
46	Apple GmbH	Manufacturer
47	Samsung Electronics GmbH	Manufacturer
48	Dell GmbH	Manufacturer
49	Epson Deutschland GmbH	Manufacturer
50	Fujitsu Technology Solutions GmbH	Manufacturer
51	SHARP Electronics GmbH	Manufacturer
52	TP Vision Europe B.V.	Manufacturer
53	Loewe Technologies GmbH	Manufacturer
54	Toshiba Europe GmbH	Manufacturer
55	Panasonic Marketing Europe GmbH	Manufacturer
56	Philips GmbH	Manufacturer
57	Grundig Intermedia GmbH	Manufacturer
58	Sony Europe Limited	Manufacturer

No.	Institution	Topic
59	Metz-Werke GmbH & Co KG	Manufacturer
60	HTV Halbleiter-Test & Vertriebs-GmbH	Test institute
61	Hewlett Packard GmbH	Manufacturer
62	Hewlett Packard Development Company	Manufacturer
63	Hochschule für Wirtschaft und Recht, Berlin	Psychology
64	Universität Siegen, Chair for Material Sciences	Material sciences
65	RICOH DEUTSCHLAND GmbH	Manufacturer
66	NEWSALES, www.elko-verkauf.de	Handel
67	Vangerow GmbH	Repairs
68	ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e.V.	Industrial association

A.3 Definitions

Cumulative energy demand (CED)

The cumulative energy demand (CED) is a measure of the overall consumption of energetic resources required for the provision of a product or service. It also includes the energy contents of the product itself. The $CED_{non\ regenerative}$ includes all non-regenerative energetic resources as primary energy values.

Global Warming Potential, GWP_{100a}

The global warming potential is a relative measure of the contribution of anthropogenous emissions over a specific time interval to heat absorption in the atmosphere and is thus an indicator for measuring the greenhouse effect. The specific global warming potential describes the greenhouse gas effect of chemical substances (e.g. methane, nitrous oxide) in comparison with carbon dioxide as CO_2-equivalent.

Terrestrial Acidification Potential, $TAP_{100\ w/o\ LT}$

The acidification potential relates to the extent that emissions are acidic or contribute to acidification in the air, in water or in soil. The main contributors to acidification are sulphur dioxide (SO_2), ammonia[120] and nitrogen oxides. Specific acidification potentials are expressed in terms of SO_2-equivalents.

Freshwater Eutrophication Potential $FEP_{w/o\ LT}$

Eutrophication in bodies of water can lead to a change in the species representation and increased biomass production in aquatic ecosystems. The aquatic and eutrophication potential of emissions in the air, bodies of water and soil are aggregated in terms of kg P-equivalent.

Photochemical Oxidant Formation Potential, $POFP_{w/o\ LT}$

The potential to form reactive substances such as ozone under the influence of chemical substances (e.g. volatile organic compounds) and sunlight in the troposphere. Ozone is harmful to flora and fauna. The contribution of substances to the formation of tropospheric ozone is expressed in terms of the POFP (in kg NMVOC-equivalent – non-methane volatile organic compounds).

Water Depletion Potential, WDP w/o LT

Freshwater is a renewable abiotic resource that is irreversibly consumed in only a view processes (cement -> concrete, hydrolysis). In some types of use, the water is only heated (cooling in thermal power plants) or releases potential energy during use (water power plants). Evaporation (e.g. during agriculture use) removes the water temporarily from human use, but does not remove it from the geological cycle. Water in the dorm of fresh water is not only a scare resource in many places, but also an indispensable “element” for the life of all organisms. It thus plays a more important role than the resources discussed above (especially fossil and mineral resources), which are primarily of interest with regard to humans. In this role, water is part of the ecosystem protection objective and should be characterized by an additional appropriate indicator. The impact indicator selected here takes water use into account in terms of the total water volume. This consists of four different types of freshwater (“lake water”; “river water”; “well water”; and “water of unspecified natural origin”). Ultimately, this is an indicator at Life

[120] Ammonia is oxidised in the soil by microorganisms to release hydrogen cations.

Cycle Inventory level for which the characterisation factor $1m^3/m^3$, which has only been formally inserted, is identical for all water types. Water consumption within the system boundaries of this study is significant in Central Europe (more precisely in Germany). Due to the sufficient fresh water supply for this geographical area, it was possible to dispense with the time-consuming research and consideration of water criticality parameters as taken into account by other methods.

Agricultural land occupation potential [ALOP)

This indicator describes the potential use of agricultural land associated with a product or product system, in terms of area (m^2) and years. Further information is provided under http://www.lcia-recipe.net/system/app/pages/search?scope=search-site&q=ALOP (accessed 02.11.2014).

A.4 Standards containing tests of lifespan or durability

EN 60335-1 Household and similar electrical appliances. Safety. General requirements: Sections 21, 23, 24, 25, and Annex C

EN 60335-2-2 Particular requirements for vacuum cleaners and water-suction cleaning appliances: Section 21

EN 60335-2-3 Particular requirements for electric irons: Section 24

EN 60335-2-4 Particular requirements for spin extractors: Sections 18 and 21

EN 60335-2-5 Particular requirements for dishwashers, Annex BB

EN 60335-2-6 Particular requirements for Cooking Ranges, Hobs, Ovens and Similar Appliances: Sections 21 and 22

EN 60335-2-7 Particular requirements for washing machines: Sections 18 and 21, Annex BB

EN 60335-2-8 Particular requirements for electric shavers, hair clippers and similar appliances: Section 21

EN 60335-2-9 Particular requirements for toasters, grills, roasters and similar appliances: Section 21, Annex C

EN 60335-2-10 Particular requirements for floor treatment machines and wet scrubbing machines: Annex C

EN 60335-2-11 Particular requirements for tumble dryers

EN 60335-2-12 Particular requirements for warming plates and similar appliances: Section 21

EN 60335-2-13 Particular requirements for drying pans, deep fat fryers and similar appliances

EN 60335-2-14 Particular requirements for electric kitchen machines: Section 21

EN 60335-2-15 Particular requirements for heating liquids

EN 60312-1 Vacuum cleaners for household use. Dry vacuum cleaners. Methods for measuring the performance

EN 60311 Electric irons – Methods for measuring the performance; Section 14

A.5 Specifications for appliance components relating to lifespan in standards

Internal wiring (EN 60335-1) The moving part is moved backwards and forwards 30 times per minute. The number of cycles is:

10 000 for wiring that is bent in normal use

100 for wiring that is bent when the user carries out maintenance.

(other values are provided in parts for specific appliances.)

Components (EN 60335-1) IEC 61058-1 is the standard for switches. At least 10 000 activations.

Electrical controls (IEC 60730-1) No. of necessary actuations, temperature controls: 10000, Operating temperature regulators 1000 (other values are provided in parts for specific appliances)

Mains cable (EN 60335-1) (values are specified in parts for appliances)

Motor (EN 60335-1) Ageing test for motor (values are provided in parts for specific appliances)

Electric cable tubes (EN 60335-2-2) Tubes are tested for resilience to compression, bending, twisting, and low temperatures

Motors (60335-2-2) Age testing

Valves (EN 60335-2-3) Valves regulating steam or water flow are subjected to 50 000 operating cycles.

Lid and door locks (EN 60335-2-4) Lids and doors are opened and closed 6000 times (defined angle of opening, speed, and force)

Strength of lid and door (EN 60335-2-4) Test with rubber hemisphere (70 mm diameter; defined hardness, attached to a 20 kg cylinder); dropped from 1 m on the middle of the lid and the door, 3 times.

Age testing for elastomer parts (EN 60335-2-5) Test to determine hardness and mass before and after submersion in cleaning and rinsing liquids at elevated temperature

Strength of glass doors and ceramic cooking surfaces and other components (EN 60335-2-6) 3 blows on the middle of the front glass with door closed; glass must remain unbroken. Three blows on cooking surface. Grid elements are loaded with 220x volume of the usable oven space (max. 24 kg).

Testing the door of cooking ovens with pyrolytic self-cleaning (EN 60335-2-6) Open and closing the door must not damage the locking system or damage the door seal. Door is closed with a force of 90 N (5000 times)

Lid and door seals (EN 60335-2-7) Lid or door opened and closed 10000 cycles (13000 for appliances with drying function) with defined angle of opening, speed, and force

Strength of lid and door (EN 60335-2-7) Test as in EN 60335-2-4; also the lid must be able to withstand deforming forces

Age testing for elastomer parts (EN 60335-2-7) Test to determine hardness and mass before and after submersion in a detergent solution at elevated temperature

Mechanical strength (EN 60335-2-8) Blows with a kinetic energy of 0.5 J against those parts than could contact the floor if the appliance was dropped. Three blows additionally against other parts, 0.35 J; cutting heads excluded.

Special requirements for the mechanical strength of appliances used outdoors (EN 60335-2-9) Test as in Part 1 but without increasing the impact energy

Requirements for glass ceramic (EN 60225-2-9) Filled vessel (total 1.8 kg) dropped from 150 mm onto the cooking area 10 times. The cooking surfaces must remain intact.

Age testing of motors (EN 60335-2 Parts 9 / 10/ 14 / 15) different requirements than in Part 1

Strength of glass ceramics (EN 60335-2-12) Section 21.101

Mechanical strength of hand-held appliances (EN 60335-2-14) The appliance is laid on a horizontal surface 700 mm above a rigid wooden board and switched on. It is allowed to fall freely. Test carried out on three new appliances. It shall not result in any electrical hazard.

Construction, special requirements for espresso coffee makers (EN 60335-2-15)

Section 22.7, Appliance subjected to double the maximum pressure for 5 min. It must not break or leak and must be suitable for further use

Power contact for cordless kettles EN (60335-2-1) Kettle is placed on based and lifted 10 000 times (power on) at a rate of 10 times per minute) and a further 10 000 times with power off. After completion of the test the kettle must be suitable for further use.

Impact resistance of cleaning heads EN 60312-1 (Section 6.5) Testing removable cleaning heads; no standard test requirements, but recommended testing up to a maximum of 500 cycles

Deformation of hose and connecting tubes EN 60312-1 (6.6), Screw spindle applying a force of 700 N to the test body. Percentage change to the external diameter is recorded

Bump test EN 60312-1 (6.7), Simulated bumping with thresholds and doorpost at a defined speed. A test full cycle involves 10 passages over a threshold, 1 bump against doorpost, 10 passages over a threshold, 1 bump against doorpost. No standard test requirements, but recommended testing for up to 500 cycles

Repeated bending of hose EN 60312-1 (6.9), No damage after 40 000 oscillations using defined test apparatus (hose attached to arm that is raised and lowered mechanically, a 2.5 kg weight attached to end of hose

Lifespan testing EN 60312-1 (6.10) The ability of a vacuum cleaner to maintain its suction performance with a partially filled dust collector is tested. The vacuum cleaner is tested in cycles – switched on for 14 min 30 secs and then off for 30 secs – and air data are recorded every 50+/-5 h. Test for a recommended period of 500 h.

Total steam duration with hard water EN 60311 (Section 14), test of scaling, carried out with hard water. The steam function is operated under controlled conditions until the steam dose falls below a specific level. For boiler steam irons the test will be continued until the steam dose falls below 5 g/min or 500 l water has evaporated (equivalent to 5 years' normal use).