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REPAIR IN THE CIRCULAR ECONOMY

EUROPEAN LEGISLATION, PRODUCT DESIGN AND BUSINESS MODELS

SUSTAINABLE SOCIETY

Credit: Eric de Vries

TU Delft OPEN

10 scientists | 4 stories from practice | 26 insights | 14 recommendations

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Contents

European legislation 7

Summary and recommendations 9

Introduction 13

#1 Repairability as a driver for the circular economy 17

#2 René Repasi is a proponent of the right to repair, both as a Member of the European Parlia. 23

#3 The new right to repair: a bold move that leaves room for improvement 27

#4 Making a profit when repair is the norm: it is possible 31

Practice #A The long road towards repair of medical instruments 35

#5 Life cycle analysis is a driver for circular production, businesses, and policies 39

#6 Disassembly: an essential enabler for repair 45

Practice #B How ATAG makes repair feasible and straightforward 51

#7 Beyond repair: design strategies that extend the useful lifetime of products 55

#8 Changing consumer repair behaviour through design 61

Practice #C The wheel reinvented: it is now replaceable 65

#9 Repair and education: not the hardest part of the transition 69

#10 Repair as a creative force: lessons from the cultural world 73

Practice #D Repair through the eyes of technical service providers 77

Further Reading 81

Colophon 85

Preface

The 'Right to repair', the forthcoming European legislation regarding the repair of consumer products, is an important step towards a circular economy. What impacts can be expected from this legislation? How will it stimulate repair? Will increased repair indeed help foster a circular economy?

The Leiden-Delft-Erasmus Centre for Sustainability and the TU Delft faculty of Industrial Design Engineering collaborated on this white paper to offer guidance in answering these questions. The central question: how and under what conditions will repair contribute to a circular economy? What are the challenges and opportunities?

We approach these questions from the fields of law, industrial ecology, business economics, design, and cultural history, allowing us to examine aspects such as business models, consumer behaviour, the potential of and limits in product design, legislation, the importance of systems approaches, and life cycle analyses.

Professionals who are actively involved in repair practices contribute by sharing their knowledge and experience. A Member of the European Parliament along with experts from education, industry, and advocacy organizations discuss practical issues and essential aspects of repair. We hope that these stories provide a broad view and inspiration.

The Leiden-Delft-Erasmus Centre for Sustainability is a collaboration between Leiden University, Delft University of Technology and Erasmus University Rotterdam. It previously published the white paper 'Critical materials, green energy and geopolitics: a complex mix'. It can be downloaded from the centre's website: centre-for-sustainability.nl

Would you like to collaborate with the Leiden-Delft-Erasmus Centre for Sustainability? We love to get in touch. lde_cfs@cml.leidenuniv.nl

Contents

European legislation 6
Summary and recommendations 8
Introduction 12

#1 Repairability as a driver for the circular economy 16
Conny Bakker
TU Delft, design for sustainability and circular economy

#2 René Repasi is a proponent of the right to repair, both as a politician and as an academic 22
René Repasi
Erasmus University Rotterdam, public and private interests

#3 The new right to repair: a bold move that leaves room for improvement 26
Alex Geert Castermans
Leiden University, private law

#4 Making a profit when repair is the norm: it is possible 30
Steve Kennedy
Erasmus University Rotterdam, systems and resilience thinking in organisations

Practice #A The long road towards repair of medical instruments 34
Bart van Straten
Director at Van Straten Medical and lecturer at TU Delft

#5 Life cycle analysis is a driver for circular production, businesses, and policies 38
Stefano Cucurachi
Leiden University, industrial ecology

#6 Disassembly: an essential enabler for repair 44
Bas Flipsen
TU Delft, reparable (re)design of production architectures

Practice #B How ATAG makes repair feasible and straightforward 48
Jan van Os
Innovation and sustainability manager ATAG

#7 Beyond repair: design strategies that extend the useful lifetime of products 54
Ruud Balkenende
TU Delft, circular product design

#8 Changing consumer repair behaviour through design 60
Ruth Mugge
TU Delft, design for sustainable consumer behaviour

Practice #C The wheel reinvented: it is now replaceable. On the advantages of modular repair 64
Willem Lijmbach
R&D-manager Freudenberg Home and Cleaning Solutions

#9 Repair and education: not the hardest part of the transition 68
Marcel den Hollander
Rotterdam University of Applied Sciences, circular manufacturing

#10 Repair as a creative force: lessons from the cultural world 72
Ellen Loots
Erasmus University Rotterdam, cultural economy and entrepreneurship

Practice #D Repair through the eyes of technical service providers 76

Further reading 80
Colophon 84

European legislation

EU Measures promoting repair currently in the process of being adopted

Since 2019, the EU has been working on a package of laws to promote the circular economy as part of the Green Deal to achieve climate neutrality by 2050. The Sustainable Products Initiative, consumer empowerment for the green transition, and the right to repair together form the Circular Economy Action Plan.

Regarding repair, the following guidelines are in an advanced stage of decision-making. Please also see article #2 *'René Repasi is a proponent of the right to repair'*.

- Revision of the existing Ecodesign Directive: Nearly all product categories should be produced more sustainably and be easier to repair and recycle. They will receive a repair score, spare parts and repair manuals must be made available, and manufacturers must provide software updates for a certain period of time.
- Empowering Consumers: addresses reliable product information. This also includes the repair score.
- Green Claims Directive: addresses misleading claims about environmental merits, and products must be able to function with spare parts from a different manufacturer.
- Right to Repair complements the consumer right to be informed on the environmental impact of consumer products and services.

In the spring of 2024, it will become clear if and how the Right to Repair must be implemented by the EU member states. The proposal includes:

- Within the two-year legal warranty period, sellers can only offer repair, unless the cost of repair exceeds the cost of replacement.
- After the warranty period, various rights and instruments are applicable promoting repair for the product categories covered by the EcoDesign Directive.

In its press release of March 22, 2023, the European Commission stated: 'The proposal will ensure that more products are repaired within the legal guarantee, and that consumers have easier and cheaper options to repair products that are technically repairable (such as vacuum cleaners, or soon, tablets and smartphones) when the legal guarantee has expired or when the good is not functional anymore as a result of wear and tear.' ec.europa.eu/commission/presscorner/detail/en/ip_23_1794

Summary and recommendations

In this white paper, experts from science and practice share their knowledge of product repair. Repair is an important pillar of the circular economy as it is more efficient to repair a product than to completely dismantle or destroy it and recycle the materials. European legislation promoting repair is in the process of being adopted.

The complete white paper, in English and Dutch, can be downloaded at www.leiden-delft-erasmus.nl/nl/home

26 *insights* from the interviews

Laws and regulations

1. The right to repair offers consumers an important additional opportunity to make sustainable product choices.
2. In thirty years' time, we haven't seen such a dramatic change to consumer law as the one that is now proposed with the EU Right to Repair Directive.
3. Non-EU producers must adhere to European repair legislation when selling their products on the EU internal market. This may improve product repairability throughout the world.
4. Two weak points of the right to repair proposal: it only applies when repair is cheaper than replacement and it doesn't limit the time allowed for repair.
5. Safety regulations sometimes hinder repair, and some repair comes with safety risks.
6. As of 2021, France has implemented a repairability index: certain electronic products must carry a label detailing its repairability on a scale from 1 to 10. It creates a level playing field.

Infrastructure

7. Easy access to spare parts is a prerequisite for swift and affordable repair.
8. Extended product warranty (currently) requires additional storage space as well as long-term agreements with spare parts suppliers.
9. Maintaining a stock of spare parts makes sense for components that need to be replaced often, but it becomes costly for parts that are rarely requested.
10. 3D printing may become an affordable and sustainable alternative for maintaining a large stock of spare parts.
11. Depending on a product's design and complexity, it can be repaired by the consumer himself or by a professional repairer.
12. With labour heavily taxed, local repair in Europe can be expensive.

Design

13. Smart product (re)design is a driver for repairability.
14. It is okay to design for professional repair. What matters most is that spare parts and proper repair toolsets are available, making repair both feasible and affordable.
15. A design containing replaceable modules can help improve repairability and reduce repair risks.
16. No matter the circular recovery strategy, it is vital that a product is easy to disassemble and reassemble. The use of glue or parts hidden deep inside make product repair difficult if not impossible.
17. In product design, there can be tensions between various circular strategies, such as product reparability versus product reliability.
18. Life cycle analysis is a valuable method for assessing the impact over the full life cycle of a product. It can help optimise product (re)design taking into account economic, social, and environmental effects.
19. The end goal is not increased repairability, but rather an increased overall lifespan of products.

Business operations

20. Companies operating on standard linear business models, in which more sales equals higher profits, may struggle in adopting repair. Innovative business models and policies are needed.
21. Certain companies, such as Patagonia, have succeeded in creating a loyal customer base by offering repair services.
22. Borrowing things instead of owning them, including the associated repairs, has been a common practice in the creative sector for a while. Much like borrowing books from a library, you can nowadays borrow clothes or lease jeans.

Society

23. Society at large, from companies to consumers, must come to appreciate the added value of repair if we are to have products that are good for both consumers and for the future of the planet.
24. Increasing reparability and overall product repair requires a comprehensive design approach that integrates product design, legislation, innovative business models, and consumer education.
25. Consumers are key to enabling the repair transition as they are the ones who decide whether to repair or replace a product. Proper product design and policies can influence their decision making.
26. Circularity is a perspective and a mentality, something that can be learned on top of subject-specific skills and competencies taught in educational courses. That is why, in education, the repair transition boils down to only a small change in emphasis.

14 *recommendations*

1. Use consumer education to discourage consumers from making climate-negative purchases with the money saved through repair.
2. Enable effective repair by ensuring the required infrastructure and sufficient skilled laborers.
3. Support local repair to minimise environmental impacts.
4. Make sure that independent repairers will have access to the code for the 3D printing of spare parts. It will make repair more feasible and affordable.
5. A device should provide fault indications, and producers should not impose software restrictions that prevent others from diagnosing or repairing the issue.
6. Investigate the effects of reducing the VAT rate for spare parts and repair-related labour. Increased taxation on materials may also make repair more attractive and product replacement less appealing.
7. Use Life Cycle Assessment and other quantitative methods as a basis for informed decision-making in support of the circular economy.
8. Involve the aftersales department in product redesign, allowing customer experiences to help guide product improvement.
9. Mandating a statutory warranty period that is slightly above the average lifespan in a product category will stimulate producers to design products that are more reliable and easier to repair.
10. There are existing design strategies that stimulate repair, such as the use of replaceable modules and stickers that provide maintenance and repair tips. Support these with policies that promote a culture of repair.
11. Explore an improved repair index that considers both repairability and product reliability.
12. Allow modular units in products to be replaced without the product losing its type certification. Customers value certification, which therefore has marketing value.
13. We must come to value the skills and craftsmanship of repairers within the circular economy, just like we value the skills of restorers in the art sector.
14. Support local initiatives such as Repair Cafés. They promote the principle of restoration and allow people to have the lifespan of their belongings extended.

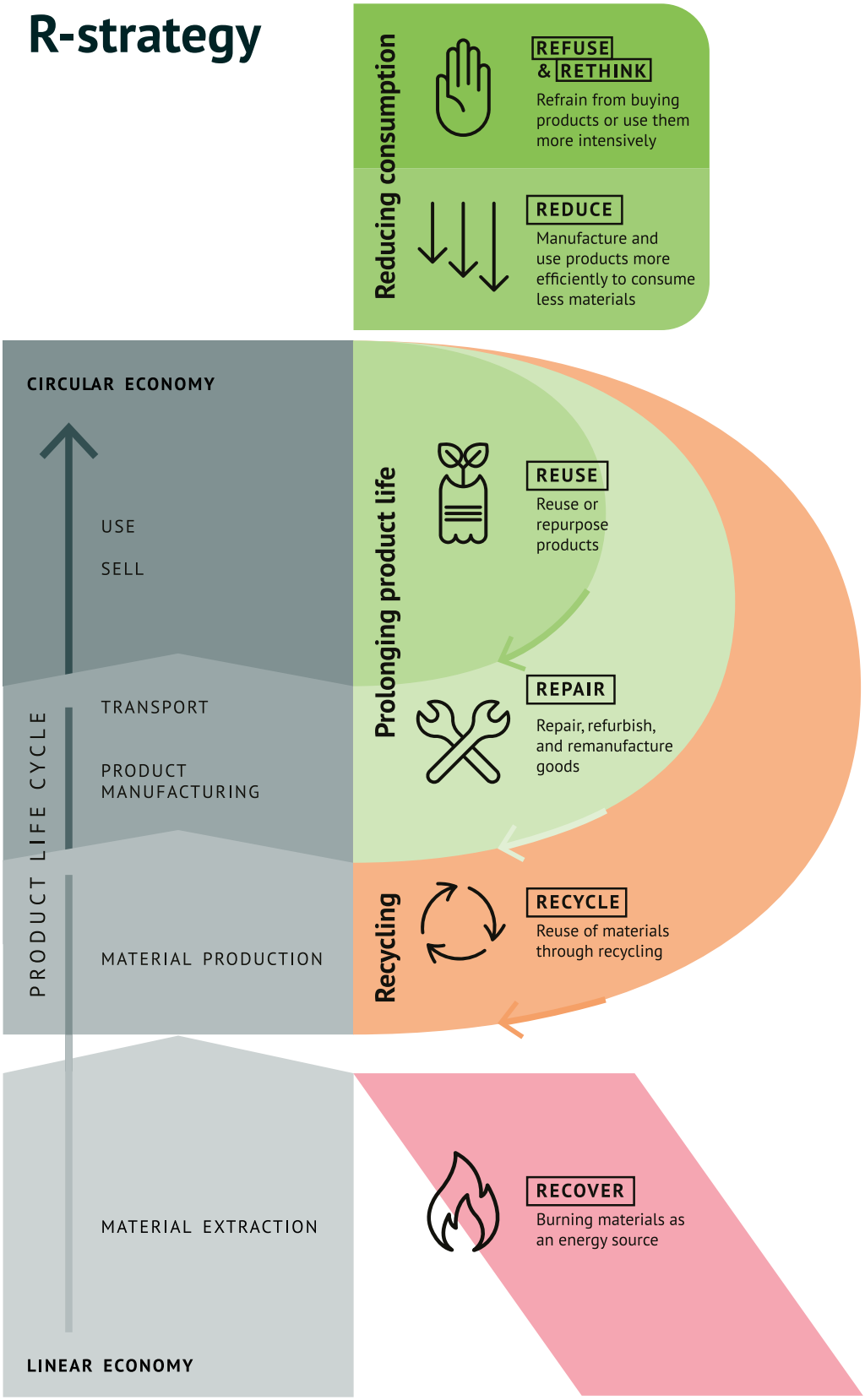
Introduction

Repair of consumer products is an important pillar of the circular economy. It clearly is more efficient than discarding or replacing a broken product, but it also saves energy and raw materials compared to recycling. The R-ladder (see illustration) shows the various circular strategies and their environmental impact.

There is a long way for repair to (again) become the norm in our society. The currently proposed Right to Repair represents a significant step forward for the European Union. In this white paper, you can read all about this European initiative and its implications for consumers, companies, and governments.

Repair is not only an academic topic. In this white paper, managers, entrepreneurs, and the Dutch association of technical service providers also discuss practical aspects of repair.

R-strategy


Reducing consumption
REFUSE & RETHINK
Refrain from buying products or use them more intensively
REDUCE
Manufacture and use products more efficiently to consume less materials
CIRCULAR ECONOMY
USE
SELL
TRANSPORT
PRODUCT MANUFACTURING
MATERIAL PRODUCTION
MATERIAL EXTRACTION
LINEAR ECONOMY
PRODUCT LIFE CYCLE
Prolonging product life
REUSE
Reuse or repurpose products
REPAIR
Repair, refurbish, and remanufacture goods
Recycling
RECYCLE
Reuse of materials through recycling
RECOVER
Burning materials as an energy source

#1 Repairability as a driver for the circular economy

CONNY BAKKER

TU Delft

Sustainable and efficient production are essential for reaching our climate targets. And repair will play an important role in reaching the ultimate goal: a circular economy. From product design to legal aspects, and from business models to consumer behaviour – this white paper discusses the added value and achievability of the circular strategy of repair.

By Merel Engelsman

Conny Bakker was one of the first researchers in the Netherlands looking into sustainable product design. As a professor in Design for Sustainability and Circular Economy at TU Delft she explores strategies for recycling, reuse, remanufacturing and product life-extension, and the business models that enable these strategies.

The Circular Economy is a concept where waste and pollution generated by products is minimized through strategies that prolong product use and that promote component/material recovery and reuse. So far, Europe has mainly established a decent recycling infrastructure. Repair as a means to increase product longevity hasn't yet received the attention it deserves; we still default to buying replacement products. But thanks to the efforts of many NGOs, consumer organisations, and grass roots movements such as the Right to Repair, repairability has gained much traction. It is also increasingly being passed into national and European legislation.

Better than recycling

Extraction of raw materials always comes with an associated energy and ecological footprint. Recycling helps reduce this extraction by converting waste into materials that can, potentially, be reused in the production process. Repair is considered a higher value circular strategy because fixing a product retains its functionality and its value. 'Repair recognises the importance of the raw material value that is lost and the environmental damage that is imposed when products are manufactured from extracted materials, used, and then disposed of in a single cycle', says Conny Bakker, professor of circular and sustainable design at TU Delft.

‘Ten years ago, I did not dare dream of the current policy intentions’

A surge in policy intentions

Recent legal milestones include the ‘Right to Repair Proposal’ of the European Commission and the release of the Dutch National Repair Registry that enables consumers to easily find professional repairers. ‘We are currently experiencing a major surge in policy intentions for repair’, Bakker says. ‘Ten years ago, I did not dare dream of this.’

Most repair legislation mainly focusses on electronics and electrical equipment. That makes sense as the scarce materials used, combined with the energy-intensive production methods, means there is a lot to gain by increasing repair and other circular strategies. ‘These products are a real challenge to deal with from both a design perspective – they are currently difficult to repair – and from a societal perspective’, Bakker says. ‘But textiles and furniture are important product groups for repair as well, with each their own unique and complex challenges.’

Repair service: from your shoes to your bed

Dutch bed manufacturer Auping is offering a restyling service for the Auronde, a bed-frame model that has been around for 30 years and is a design classic. The restyle service involves repairing and repainting the bed.

Recently, English shoe manufacturer, Doc Martens offers a repair service: drmartensrepairs.com. Very trendy, but not new, as shoemakers have been repairing our shoes since a long time.

Credit: Pexels/Cottonbro

Refurbished smart phones are on the rise: repaired, refreshed and sold again. And outdoor clothing company Patagonia encourages its customers to repair their items via Do-it-yourself videos.

Robust solutions require integrated thinking

Whereas traditional design for sustainability has aimed to achieve a positive environmental impact by focussing on the product itself, increasing a product's overall repairability requires a comprehensive, interconnected design approach that considers the product, legislation, business models, and consumer education. 'There are tensions among these elements, and even trade-offs to be weighed between repair and other circular strategies', Bakker says. 'We must therefore address all these aspects simultaneously. It is not just that companies must design better products. It is also up to us, consumers, to understand and appreciate the value of repair. If we do not change the consumer's mindset, no amount of repair legislation or product repairability will have real, lasting effect.'

Repair can come with unintended consequences

An integrated approach is also important to avoid any unintended consequences. When it comes to the consumers, it is not only a matter of undoing decades of cheap product replacements – which has resulted in the loss of the ability to repair things ourselves or even the notion that things can be repaired at all. There can also be negative perceptions around repair. 'Our research, for example, indicates that consumers may perceive repairable products as being of lower quality. This certainly is something to consider when legally mandating repairability labels for specific products. It also underscores the interconnectedness between legal and consumer aspects of repair.'

'Consumers may perceive repairable products as being of lower quality'

Another unintended consequence of repair becoming the more feasible, cheaper option, could be that consumers may spend money saved on buying more products, thereby increasing their environmental footprint. 'It is because of such potential rebound effects that we simply don't know yet whether, at a systemic level, increased repairability will reduce raw material use', Bakker says. 'This may warrant additional consumer education.'

Now is the time to act

A decade ago, there was little knowledge on how to design for repair. But over the past years, research has yielded many valuable insights and tools – from product design to legal aspects, and from business models to consumer behaviour – all of which are discussed in this white paper. 'Society at large will need to adopt these if we are to have products that are good for consumers and for the future of the planet.'

Inspired by the ongoing energy and raw material transitions, consumer enthusiasm for increased circularity also has never been higher. 'The will is there, the tools are there, now is the time to act', Bakker says. 'If all goes well, we will have normalised repair as part of everyday life. As such, increasing repairability can act as a flywheel for other circular strategies.'

Credit: Bas Flipsen

‘We simply don’t know yet whether increased repairability will lead to an actual reduction in raw material use’

#2 René Repasi is a proponent of the right to repair, both as a politician and as an academic

RENÉ REPASI

Erasmus School of Law

The right to repair constitutes the biggest change in consumer law in 30 years, says René Repasi. He is a Member of the European Parliament and professor of Public and Private Interests. 'It is indeed a paradigm shift when consumers demand repairs for their products instead of opting for replacements.' By Katja Hoiting

At the time of this interview, René Repasi is deeply engaged in the developments regarding the right to repair. Both as an academic and a politician – he is a Member of the European Parliament for the German SPD. In the fall of 2023, this parliament will debate the law as proposed by the European Commission this spring.

René Repasi is professor of Public and Private Interests at the Erasmus School of Law. He is a Member of the European Parliament for the German SPD and holds a seat in the Committee on Internal Market and Consumer Protection. Repasi is the rapporteur for the new Right to Repair legislation, one of his dossiers to foster a circular economy in Europe.

No spare parts, no network

As a professor of Public and Private Interests, Repasi considers the right to repair a revolutionary change. 'In the 1990s, consumers were granted the right to choose between repair and having a product replaced by a new one, if it turns out to be defective within the 2-year legal guarantee. It is indeed a paradigm shift when consumers will now choose repair over replacement. As a consumer you can currently only contact the seller to claim your rights. But the seller is not the producer, he doesn't have any spare parts on stock and cannot repair the product on his own. It may even be an online seller with nothing but a website. The seller therefore normally responds to a repair claim by the consumer that "it is much easier to give you a new product. You will also benefit from a new two-year guarantee while a repaired product comes with only a one-year guarantee." It is an incentive created by the old consumer law. In 30 years, we haven't seen such a dramatic change to consumer law as the one that is now proposed with the Right to Repair.

Needless Waste

It is a revolution of the utmost importance to the professor and politician. 'The question is: how do we make the transition to a

‘Governments also have an interest in producing and buying much’

truly circular economy, in which products last much longer? It is not only a matter of product quality and product repairability, but also of marketing hypes that stimulate consumerism. Take the commercials for the latest iPhone, for example. It is presented as something you absolutely must have even though it constitutes a marginal product improvement. National governments also benefit from the situation: The more we produce and the more consumers buy, the more profits are made which finance taxes and high wages.’

Yet, a throwaway culture is always a mistake, Repasi thinks. ‘Too much is being incinerated and far too little recycled, let alone repaired. It is a needless waste of raw materials. We want to create new incentives in the market that encourage the consumer to opt for repair over replacement.’

By the end of November, after the European Parliament and Council have adopted their positions, negotiations will start between the Council, Commission and Parliament: the trilogue. The goal is to reach a compromise on the final text by the end of February next year. Once the directive is adopted, the member states have 24 months to implement it into national law. Repasi doesn’t expect this to cause too many problems as the directive leaves little room for implementing diverging laws.

Empowering repairers

‘An important question is whether we are addressing the right actors. We currently focus on manufacturers. But independent repairers may be more important and perhaps we should aim at strengthening this group. They tell us that it is not the price of their own labour which makes repair expensive, but the price of spare parts. We are therefore considering adding to the proposal a rule that independent repairers must have access to the code for the 3D printing of spare parts. This will allow them to create the spare part at a reduced cost. Manufacturers, however, oppose this idea referring to safety concerns and intellectual property rights. It will be an important point of discussion.’

No free rein for Asia

Once the directive is adopted, it will be a milestone that won’t go unnoticed by other countries. Should they expect European companies to lose market shares if they are obliged to repair products, to provide spare parts, and to sell less new products?

Credit: Fixit

Whilst at the same time Asian manufacturers are free to promote their products – made according to their own standards – to European consumers online? Repasi: 'The legislation applies to anyone who wants to sell products on the EU internal market to consumers, including Asian sellers. All manufacturers will have to include the costs of repair and of maintaining a supply of spare parts in the calculation of their prices.'

There are two potential outcomes: 'Manufacturers may decide to limit their sales to the African, Asian and the United States markets. But the European market is the richest market worldwide, with the wealthiest consumers. I don't think any manufacturer would be inclined to ignore us. I also don't expect these manufacturers to develop a high-quality line of products for the European market in parallel to a low-quality production line, as this would be too costly. I therefore think that African and Asian markets will ultimately also benefit from better repairable products.'

'Or is the EU using its economic power to change things?

Passive or strong?

There's a moral side to Repasi's vision. 'Do we consider the European market to consist of a passive group of consumers that only cares about the lowest price? Or is the EU a strong, wealthy market that uses its economic power to bring about change? The latter is in line with the idea of Corporate Social Responsibility, according to which there is an economically strong market that is willing and able to pay a little extra for a positive impact of its economic power on public interests.

#3 The new right to repair: a bold move that leaves room for improvement

ALEX GEERT CASTERMANS

Leiden University

On 22 March 2023, the European Commission adopted a proposal regarding common rules promoting the right to repair for consumers. A bold and timely move, according to professor of Law Alex Geert Castermans, but we're not there yet.

By Hans Wetzels

The EU Right to Repair proposal has been adopted against a backdrop of growing environmental concerns, global warming, and a society that expects companies to keep a closer eye on how the impact of their business decisions and supply chains. 'The right to repair is but one strategy that may alleviate the pressures on our natural environment', Castermans says. 'For decades, the right to return has protected consumers against aggressive sales tactics and poor product quality. Fortunately, there's a growing realisation that a right to repair may be a more sustainable way of protecting consumers.'

Smart move

The aim of the March 22 proposal, that still needs to be passed by the European Parliament and member states, is to introduce new legislation giving the consumer the right to have the products they purchased repaired. As the European Commission states in its press release: 'Over the last decades, replacement has often been prioritised over repair whenever products become defective, and insufficient incentives have been given to consumers to repair their goods when the legal guarantee expires.'

According to Castermans, it may seem somewhat disappointing that the proposal only covers consumer rights. 'But given the limited legal competence of the European Commission, I consider it a smart move. Once the proposal has been passed into law, the Netherlands and the rest of the EU will be obligated to incorporate the new rules into their national judicial systems. 'This is a good way to ensure that the right to repair will be implemented in a consistent manner in all member states.'

Alex Geert Castermans is professor in private Law at the Institute for Private Law of Leiden University. His research focuses on the interaction between European Law and Dutch private law, especially concerning themes such as global warming and corporate social responsibility.

Credit: Miranda Vijfvinkel

More sustainable consumer law

Once implemented, Castermans believes that the legislation may have a sizeable positive impact: 'It is inherent to our society to buy ever more goods. We are taught to want new clothes as fashion trends change. This attitude deserves structural attention, but until now it has been proven difficult to address. I do feel the new right and duty to repair rules are a welcome move towards more sustainable consumer law.'

Growth, competition and repair

There are, however, still some issues that need addressing. A key challenge for the newly proposed (and other) repair legislation is the prevailing economic paradigm that expects companies to continually grow while competing with others for market share. Castermans therefore expects businesses to try to water down the legislation. 'There are many incentives for companies to tempt consumers into not making use of their right to repair, and to buy a new product instead. An especially weak point in the current legislation is that it doesn't limit the time allowed for repair. Who wouldn't opt for buying a new laptop if it takes three weeks for the old one to be repaired and returned? I also expect producers to pass the costs of the right to repair on to the consumers, by raising the prices of their products.'

'There are many incentives for companies to tempt consumers into replacing a product'

‘Mandatory repair may prove a great stimulant for a revival in European manufacturing’

Environmental impact

The proposed legislation could also have paid (even) more attention to the environmental impact. At the moment, if a product fails or malfunctions within the legal guarantee, the consumer may opt for repair or replacement, both free of charge. In everyday practice, free replacement is often chosen over free repair, with the defective but still viable item being thrown away. The new proposal explicitly prioritizes repair by making it obligatory – but only if the cost of repair is lower compared to replacing the product. ‘It is a purely financial assessment’, Castermans says. ‘The burden to the environment is still not taken into account.’

Too much information

The proposal also tries to impose ways to make it easier for the consumer to have their products repaired when the warranty has expired. One of these is an information platform where consumers can compare the repair options offered by various producers. But researchers in the United States have calculated that reading all the information provided would completely overburden the consumers who want to make an informed choice regarding this matter. Castermans: ‘All in all, the Right to Repair proposal is a good start, but it certainly leaves plenty of room for improvement.’

#4 Making a profit when repair is the norm: it is possible

STEVE KENNEDY

Rotterdam School of Management

Compared to recycling, it is much harder to make a profit when integrating repair in a business model. But it is possible, says Steve Kennedy, who researches systems and resilience thinking at the Rotterdam School of Management. 'The Right to Repair proposal is a step in the right direction, but we're not there yet.' By Hans Wetzels

Steve Kennedy is an associate professor at the Rotterdam School of Management. He researches how systems and resilience thinking can help organizations innovate to address climate change or biodiversity loss. Kennedy has been involved with Leiden-Delft-Erasmus Centre for Sustainability since its inception.

The proposal on repair legislation that the EU adopted in March 2023 asks a couple of things of companies. They must try to encourage standardization of spare parts, or provide open access as to how a product is made, thereby ensuring that independent shops can repair it. It also makes it obligatory for companies to repair their own products, but only within the legal warranty period and only if proven to be a cheaper option than having it replaced by a new one.

'It means that companies can keep operating their own linear business models – in which more sales equals higher profits – and leave repair to independents if they fear that repair would reduce sales', says Steve Kennedy, Associate Professor at the Rotterdam School of Management.'

The company perspective

Kennedy researches how systems and resilience thinking can help organizations innovate to cope with challenges such as climate change or the loss of biodiversity. But Kennedy is sceptical when it comes to the willingness of businesses to facilitate innovative strategies such as repair. 'In the end, they can continue to believe in infinite growth of throughput on a finite planet', he says. 'It will be a struggle to have them adopt repair as the business case often doesn't look too good when a company is operating a standard linear business model.

The repair process itself may be difficult, complex, and costly, especially if the products are not designed to be easy to disassemble and repair. According to Kennedy, this often makes

'Companies still want to believe in infinite growth of throughput on a finite planet'

labour costs for repair a key stumbling block. 'Companies may look into repair and find that the numbers don't add up. And even if repair can be proven to be viable by means of fundamentally redesigned business models, companies may be unwilling to adopt these when current ones are not perceived as being flawed.'

Stimulating repair by shifting the tax burden

The second Integral Circular Economic Report (ICER), as authored by the Dutch *Planbureau voor de Leefomgeving* (PBL), explicitly calls for the Dutch government to speed up the integration of repair to move its lagging transition to a circular economy forward. Kennedy looks at the past to understand how deeply rooted the problem is. 'There used to be many repair shops for household appliances in every town's main shopping street. But that was before the global economy emerged. Thanks to cheap globalized labour forces and advances in mass production, it now often is much cheaper to produce and buy a new product than to repair an old one.'

Potential business opportunities for repair

The share of economic activity from manufacturing in the EU has significantly declined, thanks to capitalist globalization and a growth in service industries. This has also impacted repair opportunities. 'Large numbers of products available on the EU market are produced elsewhere. Are we to send all defective products back to Asia for repair? Or should companies set up repair services close to their EU-customers? The first option would make no sense because of the environmental footprint, the cost and time involved. The latter means that firms must build completely new teams for repair within Europe. This can be costly with only limited certainty that it will be worth the investment. And with labour heavily taxed, local repair in Europe can be expensive. Taxing materials more and labour less will help shift the balance between product replacement and product repair.'

Nevertheless, Kennedy feels that new business models incorporating repair services are viable. It will, however, require more progressive circular thinking by companies. 'Offering a

high-quality repair service can be part of a strong value proposition to the customer. Take the Fairphone, for example, which has been specifically designed to be easily repaired by customers themselves, assisted by manuals and support. Customers may value this ease of repair or the reduced environmental impact, helping to set the company apart from its competitors.'

'Repair can be stimulated by increasing taxes on materials and reducing taxes on labour'

Selling access to a product instead of transferring ownership is another approach that can make repair services more viable. By retaining ownership, companies are incentivised to make the product as durable and easy to repair as possible. There are various examples, such as the leasing of bikes and even elevators. 'Companies that innovate their business models with circularity in mind can still make healthy profits with repair included. A body of success cases and further education on the circular economy will accelerate the adoption of repair. So will consumers who demand easy repair and the implementation of stronger repair policies.'

Credit: Mareike Bos

Practice #A The long road towards repair of medical instruments

BART VAN STRATEN

Van Straten Medical, Utrecht

Hospitals discard a large pile of waste every single day. Government intervention, and a simplified legal infrastructure are needed to make the transition towards circularity. And even then, according to Bart van Straten of Van Straten Medical, it takes guts and a lot of perseverance to establish circularity for medical instruments. By Hans Wetzels

Bart van Straten works for Van Straten Medical in Utrecht, a family business that produces, repairs, and refurbishes surgical and medical instruments. He also holds a position as researcher and lecturer at TU Delft. Van Straten is chairman of the Platform Sustainability and Medical Devices.

Not only does every patient require numerous blue plastic sheets each day, there also is a lot of packaging material and wrapping paper involved. Even the stainless-steel instruments used during surgery, as well as more complex medical devices such as catheters or staplers, are used only for a single procedure and then discarded.

'Forty years ago, most of the complex surgical instruments were reusable', says Bart van Straten. 'But as technology progressed and the complexity of instruments increased, a linear economic expansion based on mass consumption and maximisation of manufacturing volumes evolved. This is the direct opposite of a sustainable and circular model where products and materials remain in the system.'

Adopting a circular business model

Since 1997, Van Straten has worked as a general manager for Van Straten Medical, the family business that produces, repairs, and refurbishes surgical and medical instruments. In 2011, the company made the bold step to start the transition towards a circular business model, including repair, maintenance, sterilisation, and transport of medical instruments. 'It is our goal to make the healthcare sector more sustainable', he says.

Van Straten strongly believes that the 2050 climate goals our society has agreed on can only be achieved by translating them into concrete projects. 'As a medium-sized company operating from Utrecht, we are more flexible in making changes to our business operations than big corporations. Still, it was quite a

Credit: Van Straten Medical

gamble for us as well, and we still need our linear sales volumes to finance the transition to becoming fully circular.'

Reconditioning medical instruments

As an example, Van Straten refers to a blue-and-white device with a large snout: a medical stapler used during operations. 'These machines are discarded after every surgical procedure', he says. 'The problem for most hospitals is the unavailability of reusable alternatives. Producers and suppliers shifted from reusable devices to single-use devices for numerous of reasons. And whenever reusable devices are used, many hospitals don't even think about having these repaired simply because it is not in their system to do so. Legislation in many countries also requires specific hospital waste to be incinerated. That is another reason why many hospitals do not focus on repair but rather replace their devices with new ones even if they only have minor defects.'

Disposing large volumes of high value medical devices doesn't make sense – from an economic perspective, and even less so when considering that the scarcity of raw materials is driving up the prices and delivery times of these devices. 'If we are to reach the sustainability goals, the healthcare sector really needs to take responsibility and deal more sustainably with the consumption and production of medical devices.'

'It is relatively easy to save money on disposable instruments'

Hospitals can profit

In 2021, Van Straten co-authored the study titled 'A Circular Healthcare Economy', in which it was estimated that hospitals could save tens of thousands of euros each year by adopting a more circular approach towards disposed surgical instruments and stainless-steel waste – such as disposed transport carts, instrument sets, and other equipment.

Each year, large hospitals use over 100,000 reusable instruments and up that number of disposable instruments. These vary from scissors that have become blunt to €3,000 endoscopes of which only a tip is damaged. Having these repaired reduces both costs and the environmental impact of hospitals. Van Straten: 'These savings can relatively easily be realized by replacing disposable instruments with reusable ones, and by setting up a repair and preventive maintenance program.'

Policy makers must step in

With the repair of medical devices outside the scope and interest of many manufacturers, Van Straten feels that government intervention is required to help make the shift towards a full-blown circular medical economy. 'In a sense, the medical industry is not very keen on repairing their instruments as it directly impacts their sales volumes of new devices.'

He also feels that the current legal infrastructure imposes too many barriers. 'In the Netherlands, it is not legal to transport or recycle medical waste and some hospital waste must be incinerated even if it contains high value materials. You also need separate environmental permits for accepting medical devices, for cleaning them, and for recycling them. It means that increasing the repair of medical instruments is more difficult than simply convincing the hospital that repair is cheaper than replacement.

In addition to amending legislation in line with the climate goals, overall awareness must also be increased. 'Fortunately, we do see a growing intrinsic motivation in hospitals to increase sustainability, also when it comes to repairing medical devices. Revenue models in the circular healthcare economy are currently in their infancy, but intrinsic motivation and public attention will eventually convince those who don't yet adhere to circular principles.'

'Dutch Legislation requires much hospital waste to be incinerated, even when it contains valuable materials'

#5 Life cycle analysis is a driver for circular production, businesses, and policies

STEFANO CUCURACHI

Leiden University

Life Cycle Analysis is the most complete method for the assessment of environmental impact. So says industrial ecologist Stefano Cucurachi. 'It offers designers, policy makers, technology developers, and innovators much needed facts and numbers for decision-making in support of a circular economy.'

By Merel Engelsman

'Recycling does not guarantee by default that you are preventing the production of new goods or reducing the extraction of raw materials', says Stefano Cucurachi, associate professor of Industrial Ecology at Leiden University. 'Having recycled materials on the market does not mean that they will be used, rather than (higher-quality) primary materials. Increased repairability, in contrast, will always be an effective strategy. It extends the lifetime of products, thereby diminishing environmental impacts while allowing the product to keep performing its intended function.'

Stefano Cucurachi is an associate professor of Industrial Ecology at Leiden University. His research focusses on quantitative methods for assessing the environmental and social impact of emerging technologies, business models, and policies.

Life cycle analysis (LCA) is a powerful tool

For Cucurachi, LCA is the most complete method for quantitatively assessing the environmental impact because it considers the full life cycle of a product. From the extraction of raw materials, via product manufacturing and product use to the final end-of-life treatment. It also allows quantification across a wide palette of impact categories, cause-effect chains, and impact pathways. In his own research these include, among others, climate change impacts, toxicity impacts on human health and biodiversity, and impacts on the dissipation of natural resources. 'When applying LCA to assess repair strategies, one should focus on the net environmental benefit across the above set of impact categories. And thanks to recent developments, we can now also use LCA to characterize economic and social impacts.'

Credit: Pexels/Yogendra Singh

‘We can now use life cycle analysis to characterize economic and social impacts as well’

Early development stage analysis

The focus of Cucurachi lies on the early stages of innovation and on emerging business models. ‘At these stages it still is possible to make design choices at a reasonable cost, allowing features that are less preferable from a sustainability perspective to be reconsidered.’ His analyses stimulate product and technology developers to consider all life-cycle stages early on, including what might happen to it at the end of its useful life. This is not limited to repair but also covers other circular strategies.

The solar energy sector can serve as an example. ‘Innovative solar panels often use a more complex combination of materials and more energy-intensive manufacturing processes. This means that an increased efficiency in converting sunlight to electricity comes with environmental trade-offs. By applying LCA for two state-of-the-art solar cell design concepts, we were able to show that these are well-positioned to outperform the incumbent silicon photovoltaic systems in terms of life-cycle environmental impacts. We also identified certain critical processes to be further improved, such as electricity consumption during the growth of various layers in the solar panel.’

Applying holistic thinking to identify business opportunities

As Conny Bakker discussed in the introduction, integrating repairability (or any other circular strategy) is a complex process that requires consideration of the complete system. While LCA provides a comprehensive overview of the environmental effects, its outcomes should be combined with other approaches to deal with the myriad of (social, legal, and business) interactions and tensions at a systems level. Cucurachi: ‘Integrating repair into society and business models will require a broader system of services and activities to be put in place. Rather than this being considered an additional burden, a comprehensive approach can help identify creative business opportunities within this new system.’

Successful while lowering demand

Take Patagonia, the outdoor clothing retailer that provides repair and do-it-yourself education and even hosts a marketplace for repaired garments. 'Their business model contributes to a reduction in the consumption of goods, and they are thriving', Cucurachi says. 'Perhaps even more important is that they stimulated the creation of a community of customers that can further inspire others to learn. I think that taking on more of a community-based approach will have an even greater impact on maximizing repair opportunities, when compared to a purely business approach.'

True Price offers insights

According to Cucurachi, we should also put more effort into informing consumers on the true price of products they buy as part of our efforts to increase sustainability. 'The true price of a laptop or mobile phone would significantly increase when paying fair wages to those manufacturing it elsewhere in the world. This also holds when factoring in the external environmental costs of manufacturing something that has not been designed to last. True Price, for example, is a social enterprise that does such calculations for flowers, t-shirts, and various foods.'

'Patagonia lowers the demand for new products and creates a loyal customer community'

Creating a community of people that believe in a product because of its durability and repairability, and that thus are willing to pay a higher but fair price, certainly offers business opportunities. 'This goes well beyond legislation and adhering to prevailing societal sentiment. Signalling that the price is higher for such reasons is a positive message towards consumers.' Again, Patagonia is a case in point, as is Miele, the high-end washing machine company that is known and trusted for the durability of its products.

‘Repair cafés raise awareness as to what is possible and feasible ‘

Data are important, and so are social initiatives
Taking facts and numbers into consideration is essential for fostering a more circular economy, Cucurachi would therefore like policymakers to stimulate the adoption of LCA and other quantitative methods that can provide a good basis for informed decision-making. ‘Next to that, I would like policymakers to support initiatives that are minimizing the potential environmental impacts of systems, especially businesses that provide the necessary level of education and training to those that interact with them.’

Cucurachi would also like designers to be taught these quantitative assessment methods, allowing them to consider, at an early design stage, how their design choices may impact the environmental performance of the product systems they work on. But he expects the biggest push to come from social initiatives. ‘Repair cafés and the UK-based Restart Project not only help people repair their products, but they also raise awareness as to what is possible and feasible. This will push policymakers to implement new legislation, such as the recent EU repair proposal.’

#6 Disassembly: an essential enabler for repair

BAS FLIPSEN

TU Delft

Legislation can stimulate repair. But screws hidden so deeply in a product that they are nearly inaccessible are a repair nightmare. Bas Flipsen encourages circular product design by developing tools for designers and engineers. By Merel Engelsman

Each time Bas Flipsen joins the repair café in his hometown, he comes across screws that are difficult to access because they are hidden deeply within a product. 'I recommend anyone who wants to become a circular practitioner, students and professionals alike, to spend time at a repair café', he says. 'It will give then first-hand experience at how poor product design impedes repair.' It is one of the reasons why he spends much of his research time on understanding disassembly and creating valuable tools that help guide product (re)design.

Bas Flipsen is a senior lecturer and education researcher at the Industrial Design Engineering faculty of TU Delft. He is specialised in (re)designing product architectures for improved repairability and remanufacturability.

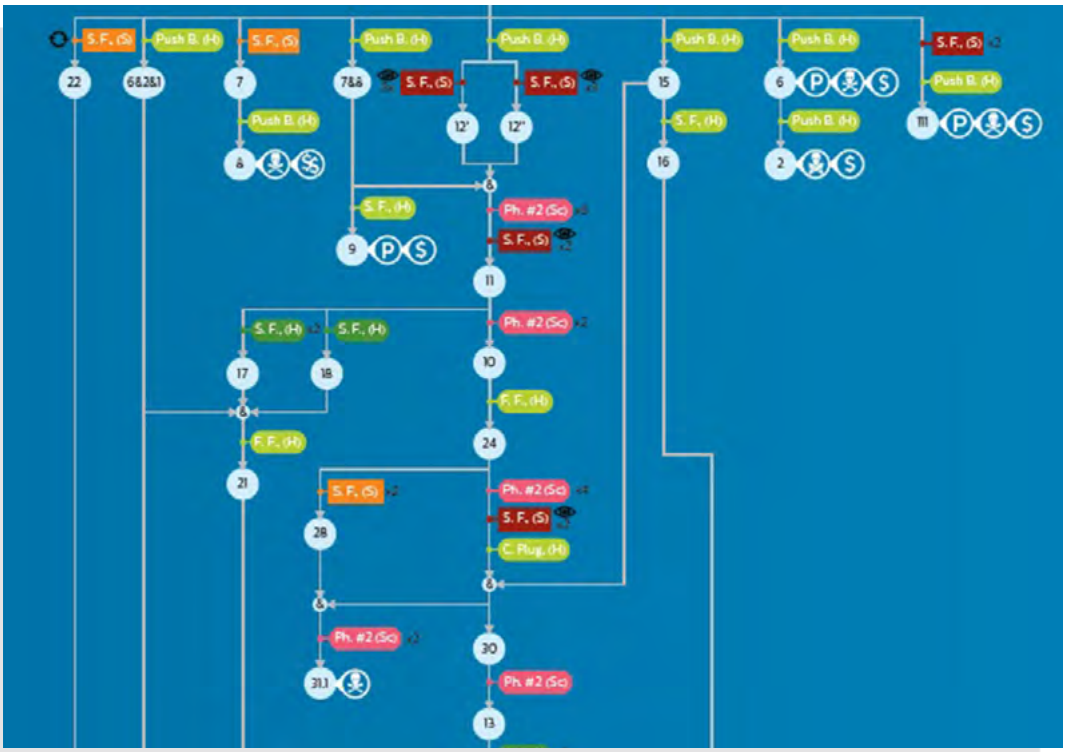
A clever map for disassembly

'No matter the circular strategy, it is vital that a product is easy to disassemble', Flipsen says. 'A Disassembly Map provides an intuitive visual representation of a product's architecture, allowing designers to identify design features that hinder repairability.' The visualisation not only considers the sequence of disassembly to reach a certain component, it also takes into account the time and type of tools needed, and whether the fasteners (such as screws and bolts) can be reused during reassembly or need replacing.

A Disassembly Map can also be used to redesign products. To increase the repairability of a product, for example, the components that are the most likely to fail should be the easiest to access for repair or replacement. This design strategy is called *surfacing*. 'Basically, you bring such a part closer to the surface, thereby reducing the number of steps needed to reach it', Flipsen says. 'For instance, you shouldn't have to spend a few hours replacing a fuse worth ten cents.' Next to surfacing, the Disassembly Map may also suggest merging various non-essential components into a single, easy to remove module (called *clumping*) or to save time by reducing the number of fasteners used to fix a certain component (called *trimming*).

Hotspot Mapping: pinpointing repair design

Obviously, not all components can be easily accessible, nor are they all equally important when it comes to repair or any other circular strategy. This is where Hotspot Mapping comes in, which helps guide designers in focussing any (re)design efforts for repair. 'Traditional repairability assessment methods focus on failure-rates and functionality of components', Flipsen says. 'Next to these priority parts, it was our goal to also consider the embodied environmental impact and economic value of the various components.' The time and strength needed to reach a certain component are also part of Hotspot Mapping. After all, a valuable and still-functioning part buried deeply inside a broken product is hard if not impossible to repair and basically lost as donor part.



A disassembly map shows possibilities for repair, and any difficulties.

A starting point for both Disassembly Mapping and Hotspot Mapping is an existing product, which is completely taken apart. Applied in combination, they point designers towards parts in the product architecture which are most critical for ease of disassembly, while also providing guidance on how to redesign the product. 'We provide masterclasses for professional designers and offer it to students as an elective master's course.'

'You don't want to spend a few hours to replace a fuse worth ten cents'

Printed spare parts

Flipsen's research extends beyond direct product design. Take 3D-printing, a modern technology that at first thought seems ideal for custom-creating spare parts that are not or no-longer available. 'As part of the EU-funded Sharepair project, we looked into its viability in a repair café setting', he says. 'But without access to the digital 3D model of the broken part, it turned out to be too cumbersome a solution.' Its application was also limited because of various quality requirements, such as heat resistance, food safety and mechanical strength. 'You simply can't replace a metal drill cog with the plastics used for 3D printing. There is a reason why the original cog broke.'

But he hasn't given up on the idea and is currently looking into how 3D-printing for repair may be of benefit to companies themselves. There is currently legislation underway stipulating how long a period of time spare parts must be available. 'Long-term storage of spare parts is costly and a waste of materials if they are not used', Flipsen says. But what about the printing of metal parts? 'Professional metal and powder-bed printers could meet quality requirements and provide instant delivery simply by mailing the digital 3D model of the part, thereby lowering the need to stock spare parts.' Later on in this white paper, Jan van Os discusses ATAG's efforts into 3D printing of spare parts for kitchen appliances.

Repair café in Amsterdam

A shift in repairability thinking

It appears as though an increase in repair legislation will lead to a shift in product design, in business models and in consumer perception. Some of these shifts are already visible, for example in service-based business models. 'You can now lease high-end headphones', Flipsen says. 'Because the company owns the product, they have a strong incentive to keep it functional.' This is reflected in the headphone design, with some headphones having modular parts so the consumer can easily repair the headphones at home. The company only needs to mail the customer the replacement component. 'Likewise, companies leasing bicycles to students were quick at redesigning these bikes to reduce failure rates and allow efficient servicing.'

'Repair cafés offer first-hand experience at how poor product design impedes repair'

When it comes to facilitating sustainable consumption, Flipsen also foresees a great future for Urban Resource Centres – a combination of a Fab Lab (a small-scale workshop offering personal digital fabrication), a second-hand store and a recycling centre. 'You enter with something that is broken, and never leave without a working product. If they cannot repair it, you can buy a second-hand replacement for little money. The broken product will be used for spare parts or will be recycled. In the future, these may also feature advanced 3D printers for the on-site manufacturing of spare parts.'

'A valuable and still-functioning part buried deeply inside a broken product is basically lost as a donor part'

Practice #B How ATAG makes repair feasible and straightforward

JAN VAN OS

ATAG Nederland BV, Duiven

Repairability of their kitchen appliances and offering repair services are a core part of ATAG's business model. Innovation and Sustainability manager Jan van Os discusses how the company has integrated repair into its business units. By Merel Engelsman

Product development at ATAG typically comes down to making improvements or adding innovations to an existing line of products. Repairability is on the agenda from the moment such product development is initiated, with the after sales department being invited to provide feedback on customers experiences with the older product generation. The strong and weak points of the existing product are then fed into the design process for the new product.

Jan van Os is innovation and sustainability manager at ATAG Nederland BV. He studied Industrial Product Design at The Hague University of Applied Sciences and started his career as a product engineer at ATAG.

'Our company policy is that most repair issues should be solvable within thirty minutes', Van Os says. 'The design guideline therefore is for products to be easy to dismantle and repair. For example, products inside wooden counters are designed so they can be opened from the top rather than having to access the electronics from the bottom – for which you'd have to remove all the drawers.' There is a financial reason behind this approach. ATAG provides at-home repair services as their appliances are typically too large for customers to mail in or bring to a service provider. Easy access allows swift repair, reducing the associated labour costs.

Technical know-how of service employees

Next to easy repairability of the appliances themselves, ATAG's internal processes in support of repair have also been optimised over the years. 'Our service callers have sufficient technical knowledge to be able to translate the customer's issues into the tools and parts that are needed to fix the problem', Van Os says. 'This information is gathered, and the appropriate components are pre-loaded into the repair toolbox before the repairer sets out to visit that day's clients.'

‘Most repair issues should be solvable within thirty minutes’

The company is also looking into developing products that provide an error code that will be transmitted, informing the after sales department, the service engineer, the repair man and the consumer of what will be needed for that call. On top of that, an internal trainer teaches in-house repairers about the products and the organisational processes. ‘What we don’t want is a service employee not being able to come up with a solution when out in the field.’

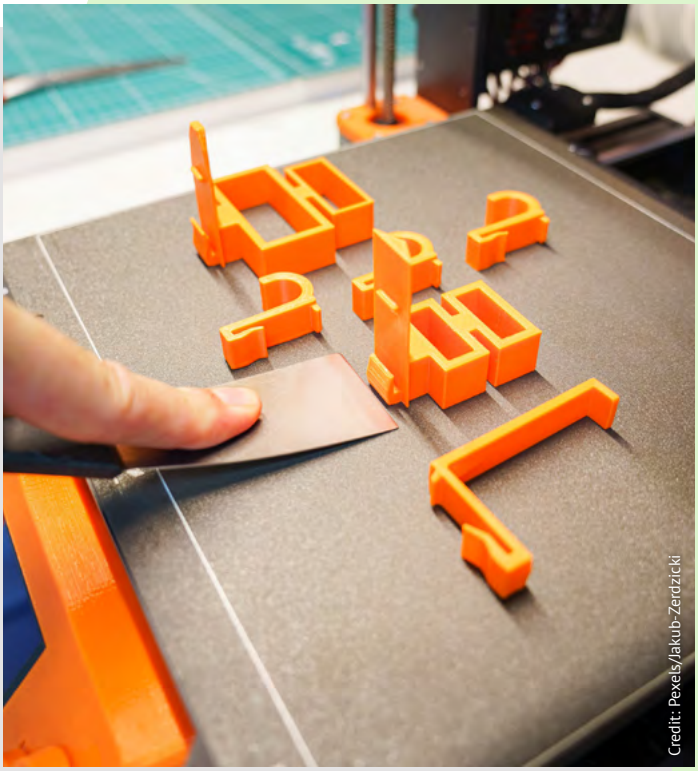
From a database to FaceTime

To further facilitate repair and technical solutions, ATAG has an internal database system. Van Os: ‘Technical bulletins describe issues and solutions for a particular line of products, and these are shared with all engineers. External engineers that work for us can also access this database when needed and we use modern communication lines – FaceTime and other visual tools – to ask for further assistance in problem solving.’

Spare parts: storage or 3D-printing?

ATAG has up to a ten-year guarantee on their products, and they are trying to increase this to fifteen years. The company enters into long-term agreements with its suppliers to ensure availability of spare parts over these long time periods. ‘We have a large building for storing service components. Even so, components may be out of stock meaning there is a two to three weeks waiting period’, he says. ‘This is frustrating as we then need to decide on replacement over repair. We are currently investigating 3D printing as a means to address long-term availability and to limit the additional storage space required.’

‘What we don’t want is a service employee not being able to come up with a solution when out in the field’


Credit: Pexels/Jakub-Zerdzicki

‘Spare parts may sometimes be out of stock. That is frustrating’

Van Os also is in favour of repairability indices that provide consumers with information regarding the repairability of a product. ‘This may require an additional effort by the product manufacturer, but it also increases transparency as to the cost of the product’, he says. ‘It may lead the consumer to choosing the higher-priced, but more durable and easier to repair product, which is good for the brand.’

#7 Beyond repair: design strategies that extend the useful lifetime of products

RUUD BALKENENDE

TU Delft

The most repairable product may not be the most sustainable product. Increasing overall product longevity is the goal, which may require a designer to balance repairability and durability. Ruud Balkenende, Professor of Circular Product Design aims for maximum societal impact by optimising the entire product chain for sustainability.

By Merel Engelsman

Ruud Balkenende is Professor of Circular Product Design at the Industrial Design Engineering faculty of TU Delft. He worked at Philips Research for 25 years, during which time his focus shifted to recyclability, sustainability, and resource efficiency. In his current research he considers the entire product lifecycle, focusing on repair, remanufacturing, and recycling.

Repair prevents a product from entering the waste stream too soon while also reducing the creation of new products and the associated environmental damage. 'The ultimate goal is to raise the sustainability of a product by extending its useful lifespan', says Ruud Balkenende, Professor of Circular Product Design at TU Delft. 'As such, repairability is not a stand-alone goal but one that needs to be aligned with designing for other circular strategies.'

Tensions in product design

A product is considered repairable if the underlying problem can be diagnosed, the broken part accessed, then replaced or fixed, and the product reassembled into its original working order. This may make design for repair sound somewhat straightforward, but it isn't. 'Sometimes, indeed, it may be a mere matter of making a certain screw more easily accessible', Balkenende says. 'But often, there is tension between designing for different circular strategies. Increasing product repairability – for example by using screws instead of glue – may reduce product reliability, thereby affecting product lifetime.' In many cases, good design can overcome any such trade-offs, and various tools have become available to help guide the designer in achieving just that. Some of these are addressed in the article on disassembly by Bas Flipsen.

‘A product that is easier to repair may have a shorter overall lifespan’

But just because a product is easy to repair does not mean that it will actually be repaired. Design for repair therefore needs to consider the entire product chain – from the availability of affordable spare parts and an infrastructure that enables product repair, to the willingness of users to repair. Balkenende: ‘There are many non-technological aspects to design for repairability. If we ignore these in research or in practical implementation, the societal impact of repairability will be small.’

Repair solutions do not need to be super technical

Typically, the design focus for a (new) product is on keeping manufacturing costs low, which means that repairability may not make it into the design brief. A lack of knowledge may also play a role, such as how to design for repairability. ‘But increasing repairability certainly is not a matter of pending technological innovation’, Balkenende stresses. ‘In our research, we find that the challenge in improving overall repairability from a design perspective lies in translating existing approaches into real societal impact. The tools are there, but the dynamics may shift – for example to repairing or replacing modules rather than individual parts because of electronic components becoming ever more integrated.’

Repairable by whom?

Repairability of a product, and who can (be allowed to) do it, largely depends on how its components are joined together. ‘We must be careful not to presume that it will be the consumer doing the repairing’, Balkenende says. ‘It is okay to design for professional repair, such as the use of glue connections in cell phones. What matters most is that spare parts and proper repair toolsets are available, thereby making repair – either by the consumer or a professional – feasible and affordable. Again, none of these are technological aspects.’ There could be safety issues, and these are often raised by manufacturers as a reason to limit self-repair by users. But research at TU Delft has shown that these can be tackled with proper product design.

The French repair index.

An improved repair index

Many of the aspects just mentioned come together in the French repair index, a scoring system meant to inform consumers about the repairability of electrical equipment that is currently applicable to five product categories. It considers the availability of documentation, ease of disassembly, the price and availability of spare parts, and product specific aspects such as the software. 'The index has already encouraged various cell phone manufactures to improve repairability of their products', Balkenende says. 'At the same time, it is far from perfect.'

For one, many different aspects are scored but critical aspects are not weighted enough, resulting in misleading outcomes. A high overall score can, for example, be obtained even without providing any spare parts or by having a product that is impossible to disassemble. 'In the PROMPT project, financed by the European Commission, we are collaborating with various consumer and test organisations in developing an improved repair index', Balkenende says. 'We have recommended applying thresholds to the repair index. For example, a high overall score

'There are many non-technological aspects to improving repair through design'

should require a minimum score in each sub-category (such as spare part availability) to ensure that the product is indeed repairable and usable afterwards.'

Furthermore, the French repair index only considers repairability while, as mentioned, the real goal is to increase overall product and component longevity. 'Our improved repair index will therefore assess premature obsolescence, considering both repairability and product reliability. It is meant to become a European standard.'

Establishing extended warranty as a policy strategy

In addition to improvements to the repair index, Balkenende would like to see a statutory warranty period being mandated, to be set at slightly above the average lifespan of products within a product category. 'This is a double-edged sword for increasing sustainability. It will force producers to design products that are more reliable and easier to repair, while simultaneously triggering users to consider repair. I realise there will be regulatory issues for policy makers to solve, but mostly it is cold feet.'

'We must be careful not to presume that it will be the consumer doing the repairing'

Credit: Pixabay/Curioso_Photography

#8 Changing consumer repair behaviour through design

Credit: Kirsten van Santen

RUTH MUGGE

TU Delft

Thanks to relentless marketing, cheap products that can be ordered with a single mouse click, and high wages, we have lost both the ability and the will to repair. Professor of Design Ruth Mugge sees opportunities to reverse the situation.

By Merel Engelsman

It is hard to blame consumers for considering (self- or professional) repair an expensive, time consuming and difficult task, because it often is. And unlike flying, meat consumption, and energy use, the detrimental environmental effect of product replacement hasn't yet been ingrained in consumer's minds. Conversely, anybody knows how to order a new product with a only few mouse clicks, and you can have it delivered the next day. This is just one of the reasons (next to various psychological reasons such as curiosity and novelty) why replacement often is preferred over repair.

Ruth Mugge is a Professor of Design for Sustainable Consumer Behaviour at the Faculty of Industrial Design Engineering. Some of her research interests are product perception, design for behaviour change, design for the circular economy, and design to extend the product lifetime.

But not all repair is cumbersome, and consumers can be made aware of that. 'Stimulating repair requires a change in current consumer behaviour', says Ruth Mugge, Professor of Design for Sustainable Consumer Behaviour at TU Delft. 'It may be difficult, but it certainly is not impossible. A concerted effort by designers, companies, and policy makers can make repair the social norm. We must address this because consumers, being the ones who ultimately decide whether to repair or replace, are key to enabling the repair transition.'

Three ingredients

Behavioural theory suggests that there are three important ingredients to behaviour change: people need to have the ability to change, they need to be motivated to change, and they need to be prompted by a trigger. 'In case of repair, the trigger often is a product's malfunctioning', Mugge says. 'Then, design should be aimed at raising the person's ability and/or motivation to fix the product. It is important to realize that it is the specific combination of these two aspects that determines whether behaviour change will take place. For example, if

motivation to repair a product is likely to remain low, it can still be stimulated by greatly raising a person's ability to repair.'

Repairing with gold glue adds emotional value.

Enabling the can-do attitude

Design provides several means to increase the consumer's ability to repair their products, or have them repaired. From a service perspective, this can include offering repair within a single day or even a few hours at a price that is competitive with new products, or even with replacement products. 'However, these still don't address some perception-related barriers', Mugge says. 'For example, we are no longer used to repairing products and many consumers perceive products advertised as being repairable as being of lower quality. That is where the product perspective comes in. Product design can enable people to experience a 'can-do' repair mentality.'

Helping people understand what is wrong with a defective product is one such design strategy. This especially holds for electronic products as these are often considered a black box. 'In our research, we showed that a fault indication can help people in diagnosing the problem. Think of a light that switches on or an error message indicating that the battery needs to be replaced. Likewise, we have shown that a modular product design – in which the product consists of several modules that can easily be removed and replaced – also increases repair.'

Instructions and maintenance tips

Later on in this white paper, Willem Lijmbach provides a practical example: his R&D department developed a replaceable wheel module for a vacuum cleaning robot. Mugge: 'Ideally, feedback about self-repair is accompanied by step-by-step instructions in a manual or on the product itself – similar to the instructions on a photocopier – thereby lowering the bar for self-repair.

'We must address deeply rooted convictions about repair'

Another good example is provided by coffee machines, many of which are discarded when only needing a relatively simple repair. 'This problem was tackled in a Master thesis project',

Credit: Unsplash/Janaya Dasiuk

Mugge says. 'The student developed a simple sticker containing an NFC-tag: near-field communication. You can scan it with your phone, just like a QR-code. It directs the consumer to a website with repair and maintenance tips, thereby raising the consumer's ability to fix their defective machine.'

Mental bookkeeping

Next to ability, behaviour change demands a certain level of motivation. This can be fostered by addressing any one of the many trade-offs being considered by a consumer in choosing between replacement or repair. An important financial aspect is the so-called 'mental book value' – a person's perception of the value of a product decreasing over time. Mugge: 'Consumers may, for example, write off a washing machine in eight years and smartphones in only two to three years. Once written off, consumers feel like having gotten their money's worth and find it reasonable to replace it – especially so when the current product has some defect.'

Companies, designers, and policy makers could explore possibilities to extend this mental book value. Seeing more remaining value in their malfunctioning products, consumers are more likely to opt for repair. Mugge: 'Why should a smartphone have such a short (mental) lifespan? We can probably design a product to convey durability. Or we can add a label communicating the actual lifespan and the number of years the manufacturer will provide software updates. In my upcoming research, I will explore this and additional opportunities.'

'It takes eight years to mentally write off a washing machine, and often only two to three years to write off a cell phone'

The community spirit of repair cafés

What may also help is for people to become aware that repair behaviour can provide additional benefits, such as it being something fun to do, or because the result is something to be proud of. 'In repair cafés, the community experience contributes to the overall repair experience. Or take the Japanese repair technique in which ceramics are repaired with golden glue, giving it a novel and attractive appearance, and adding (emotional) value to the product.'

Practice #C The wheel reinvented: it is now replaceable

WILLEM LIJMBACH

Freudenberg Home and Cleaning Solutions, Weinheim

One of the inventions that R&D manager Willem Lijmbach is most proud of, is the wheel. That is to say: a replaceable wheel module of a vacuum cleaning robot. 'You only need to remove three screws.'

By Senay Boztas

Willem Lijmbach is R&D manager at Freudenberg Home and Cleaning Solutions, a German company that owns cleaning product brands and systems. He studied Industrial Design Engineering at TU Delft and believes that designing for repair is an intrinsic part of product engineering.

One way to enable repair is by using bigger modules, so a company doesn't need to have loads of separate spare parts on stock. 'Some years ago, my department designed a vacuum cleaning robot', says Willem Lijmbach, R&D manager at Fredenberg Home and Cleaning Solutions. 'The wheel in the back will typically be the first part to be damaged, because of hairs and debris. We therefore redesigned it to be easily replaceable by removing three simple screws. We send the consumer the complete module, consisting of the wheel with the tyre, the motor, and the gear box. Anybody who can handle a screwdriver can replace it. We also offer one wheel type for all our robots, making it easier for us to offer this kind of service.' There is a limit to using ever larger or more expensive modules. At some price point, the consumer will prefer a new product over an expensive replacement module. And with large modules one also replaces non-faulty components.

Utilizing repair to promote brand reputation

Designing consumer products is a balance between cost-effective production, maximum reliability for the expected lifespan and maximum repairability for elements prone to wear and tear. 'There's definitely a price point under which people don't even consider the idea of repairing, unless they are repair enthusiasts', Lijmbach says. 'Our products are right at the tipping point when it comes to electronics. At around €100 they are expensive enough for consumers to be annoyed when they fail, but not as expensive as the products of white goods manufacturers. It's because of this higher price that white goods manufacturers can afford a full ecosystem of repair shops and spare parts.'

Cheaper products may be considered disposable by many consumers, leading to fewer complaints. But at Freudenberg, they want to offer repair opportunities as it helps maintain brand reputation. 'One reason for people to opt for a branded product is that they know they can still buy the consumable parts in ten years, making it more worthwhile to repair the product.'

'It comes down to risk calculation: how often will something break, and what are the associated costs?'

The challenge: stock costs

The company offers spares for parts that people might simply lose (such as chargers) or that might be the first to degrade or fail. Freudenberg mails these parts to the customer who will then need to replace them. 'This sounds straightforward, but the challenge for us is in stock management: ordering enough and maintaining sufficient supply', Lijmbach says. 'There are high costs associated with maintaining a spare part number is. It may therefore be cheaper to replace the failed product, rather than keeping spare parts. For example, we have a window vacuum cleaner for which we only get one or two calls each year for a replacement charger.'

Incredibly efficient

Companies also design their products to be produced incredibly efficiently and affordably', Lijmbach says. 'If you aim for the lowest possible production costs, any improvement to allow a repair comes with an additional cost. As such, there may be trade-offs between *economic* and *ecological* value. It all comes down to risk calculation: how often does something occur, and what are the associated costs? Even for a product that sells half a million pieces a year, you may only receive a handful of requests for spare parts. That may say something about the quality of the product, but also about people's willingness to have their purchased product repaired.'

Laws can help...

Legal frameworks, laws, can be helpful in terms of justifying the expenses needed to improve repairability. 'In the future, some countries will mandate companies to keep spare parts in stock for a number of years', Lijmbach says. 'And in France, they already have a repair index: as of 2021, certain electronic products must carry a label detailing its repairability on a scale from 1 to 10. That is a good thing because it puts everybody on a level playing field. It would also help if legislators thought

'You only need to remove three screws to replace the entire wheel module'

carefully about product standards. Mandating the use of USB-C ports for charging, for instance, makes it easier to replace a charging cable.'

... Or hinder repair

'From our perspective, there is also quite some safety legislation that impedes repair. There is an inherent safety risk if consumers try to replace components that operate at 220 volts. That is why, in some cases, we try to make repair impossible by using specialised screws that make certain components inaccessible. We also refrain from providing technical information that might make us liable and warn that the warranty is voided when a certain label is removed.'

A solution would be to use plug and play modular units for high-risk repair components, allowing consumers to replace them. Currently after repair, however, a product is no longer covered under its type certification (as indicated by the CE mark). Lijmbach: 'It is common, but not mandatory, to have vacuum cleaners and coffee machines CE marked. It shows customers that the device has been checked by an independent organisation, and it reduces the company's liability exposure. It would be helpful if product certification rules support more repair scenario's.'

The consumer is key

It's not only about legislation and companies. 'Consumer behaviour is key, even for a company with green ambitions such as ours', Lijmbach says. 'It is up to them to opt for repair or replacement. What we, as companies can do, is to make a product as long-lasting as possible. A unified repairability label may also help sway consumer sentiment and take away caveats towards opting for repair.'

#9 Repair and education: not the hardest part of the transition

MARCEL DEN HOLLANDER

Hogeschool Rotterdam

Will we have sufficient skilled workers to design repairable products and to repair them? 'Only a small change in emphasis is needed in education', says commercial designer and professor in Circular Design Marcel den Hollander. By Merel Engelsman

Despite many breakthroughs in technology, logistics, information technology and environmental awareness, linear business models still dominate. 'But now we want to transition from *sell more, sell faster* to a circular economy,' Den Hollander says. 'This means we will have to establish an entire infrastructure for product repair, including a pool of skilled laborers.'

Marcel den Hollander studied Industrial Design Engineering at TU Delft and became a commercial sustainability designer. In 2018, he received his doctorate degree in Circular Product Design. His research into Products that last serves as the basis for the government supported CIRCO. In 2021 he became Lector Circular Design & Manufacturing at Rotterdam University of Applied Sciences.

Educational institutions will have to adapt accordingly, even though it is hard to predict what the characteristics of the circular economy will ultimately be. But where a fundamental change is required in business models, product design strategies, and consumer awareness, Den Hollander thinks that education will only need a small change in emphasis. 'Circularity is a perspective, a mentality, on top of subject-specific skills and competencies. And the beauty of it is that once you have seen the circular light, you can never again unsee it.'

Teach the Teacher with video material

Since 2015, the CIRCO programme, supported by the Dutch government, helps in engaging small business owners and creative professionals in the circular economy. It has yielded a wealth of video material on all circular strategies, including repair. 'The video material is very useful for the education sector,' Den Hollander says. 'Together with an educational need it has given rise to the CIRCO *Teach the Teacher* track. Dozens of lecturers at the Rotterdam University of Applied Sciences and other Higher Vocational Education (HBO) institutions have already completed this voluntary track.'

Den Hollander was present at many of the lesson days. 'The educators see the circular light the moment you start

explaining that there is more to circularity than recycling. They also immediately realise how circular thinking can best be incorporated in their curriculum. This CIRCO track can also be rolled out to Intermediate Vocational Education (MBO) institutions, but I'm not aware of this already happening.' For Den Hollander, implementing circularity into vocational education curricula is best left to the educators themselves. 'Nobody has a better understanding of their field of knowledge.'

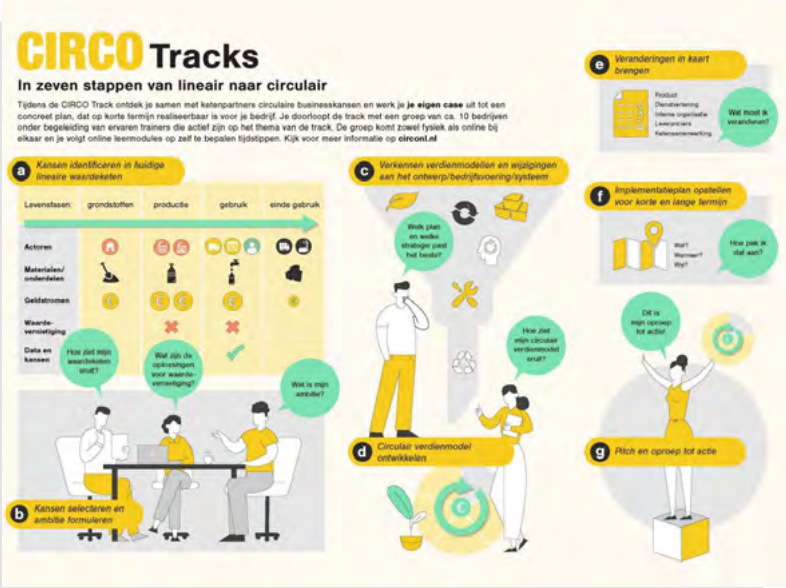
'Educational professionals see the circular light the moment you explain that there is more to circularity than recycling'

Increased repair is an inevitability in the transition to a circular economy. But what products will be repaired, who will do the repairing and where? In other words, what kind of skilled labour will society need? That is not something to be predicted with scientific accuracy, but Den Hollander is willing to make some suggestions.

Coordination in the entire educational chain

Next to the kind of product, the skilled labour needed also depends on how the product has been designed. 'You have repair and repair,' Den Hollander says. 'Some repairs can be made by the consumer. But it takes a trained technician, or even an expert, when it becomes too complex or too dangerous.' Modular design (in which, for example, hazardous parts may be enclosed within an easily replaceable module) can shift this balance somewhat. 'But then the expert will still be needed to take the module apart, fix what is broken, and put it back into good working order.' Depending on ability and experience, a different worker may therefore be needed at various positions in the repair chain.

Den Hollander thinks that effective design for repair and other circular strategies can only come to fruition with close coordination in the entire educational chain. 'To put it very simply, someone with a university degree comes up with a design principle that someone with a higher vocational degree will need to translate into something practically usable', he says. 'And somebody with an Intermediate Vocational degree must be able to skilfully fabricate it. I once received a prototype that hadn't been milled in accordance with the technical drawings we sent, but it turned out to be the only way to make it work. We must harness these skills and practical knowledge if we want to maximally extend overall product lifespan. The Rotterdam University of Applied Sciences therefore looks for



In a CIRCO Track companies discover circular opportunities together.

collaborations with both universities and Intermediate Vocational Education institutions.

Vocational pride

With a small change in emphasis in existing vocational tracks likely serving the purpose, there may be no need to establish educational tracks dedicated to repair alone. 'Those graduating in the upcoming years may of course opt to specialise in repair,' Den Hollander says. 'People in repair cafes keep telling me that this kind of work is greatly appreciated and certainly provides added value. A broken product, an upset product owner, and you can make all the difference. Repairing a product brings joy, even more so because it increases sustainability. Repairmanship truly is a profession with vocational pride.'

'I once received a prototype that hadn't been milled in accordance with the technical drawings we sent, but it turned out to be the only way to make it work'

#10 Repair as a creative force: lessons from the cultural world

ELLEN LOOTS

TU Delft

Real and lasting change towards a more sustainable society requires a change in the mindset of consumers. Dr Ellen Loots shares her thoughts on how the cultural world helps make repair become part of the social fabric. By Senay Boztas

The idea of borrowing things rather than owning them is often a key part of communal ownership in the creative sectors. And with it comes an expectation of longevity, repair, and reuse. Think of libraries and museums where the same item adds value to the lives of many people. 'In the context of the circular economy, we observe a similar shift from product ownership to much more sustainable product usership', says dr Ellen Loots, assistant professor in cultural economics and entrepreneurship at Erasmus University Rotterdam. 'This is especially explored by the younger generation in relation to fashion – leasing their MUD jeans and borrowing clothes from the LENA library, for example. Repair is also emerging as a hip business model, with United Repair Centre and Mended as Dutch examples.'

Ellen Loots is an assistant professor in cultural economics and entrepreneurship at Erasmus University Rotterdam. She has studied value co-creation in circular design processes, the preservation of cultural heritage and the role of community participation in sustainable institutions.

Repair adds value

It's not only saving on raw materials and the energy needed for producing replacement products where repair adds value. One of the principles in the 2009 manifesto on repair of the Amsterdam-based design collective Platform21 is that '*every time we repair something, we add to its potential, its history, its soul and its inherent beauty*.' Loots: 'If we can ingrain this attitude into consumer's minds, we can disincentivise them from discarding (temporarily) broken products. Think of Kintsugi, the Japanese gold-glued pottery repair technique from the 15th century, in which repair also increases an object's sentimental value. The younger generations also sets the example by allowing their jeans to become teared.'

‘Every time we fix something, we enhance its intrinsic beauty’

Valued artisans

The Dutch and Belgian repair café movement is an initiative that elevates basic repair skills to importance at a community level. Growing rapidly in numbers, they are becoming an integral part of the urban fabric. ‘In the cultural world, people with repair skills are valued artisans as they are essential for restoring and preserving our heritage. Depot Boijmans Van Beuningen does not only preserve the museum’s art collection, it also allows visitors to see restorers at work. And the ‘Ambacht

in Beeld festival' promotes and preserves our artisanal heritage through interactive education. Likewise, we need to acknowledge the skills and craftsmanship of repairers within the context of the circular economy.'

'In the cultural world, people with repair skills are valued artisans'

Credit: Unsplash/Maxim Kotov

Practice #D Repair through the eyes of technical service providers

Techniek Nederland is the Dutch association of technical service providers, installation companies and the electrotechnical retail industry. They represent more than 6,000 companies that are active in designing, supplying, installing, and maintaining 'smart technology' – from heat pumps to industrial installations. In this article, they offer their experience and view on repair.

By Merel Engelsman

Policymakers are enthusiastic

In our collaborations with various ministries we feel that policy makers are on board with the idea of repair being an essential ingredient of the circular economy. The initiative for a National Registry of Repair Services ('Nationaal Reparateursregister') is a case in point. It has been initiated by TechniekNederland and the Ministry of Infrastructure and Water Management, in collaboration with the Central Register for the Technology Sector ('Centraal Register Techniek').

Producers are reluctant

Theoretically, repair is a sound business model, and many of our affiliated servicing companies are positive about the concept of repair and supportive of decreasing waste – especially electrical waste and electronic waste. Manufacturers, however, appear to be hesitant and/or puzzled about incorporating repair into their business models.

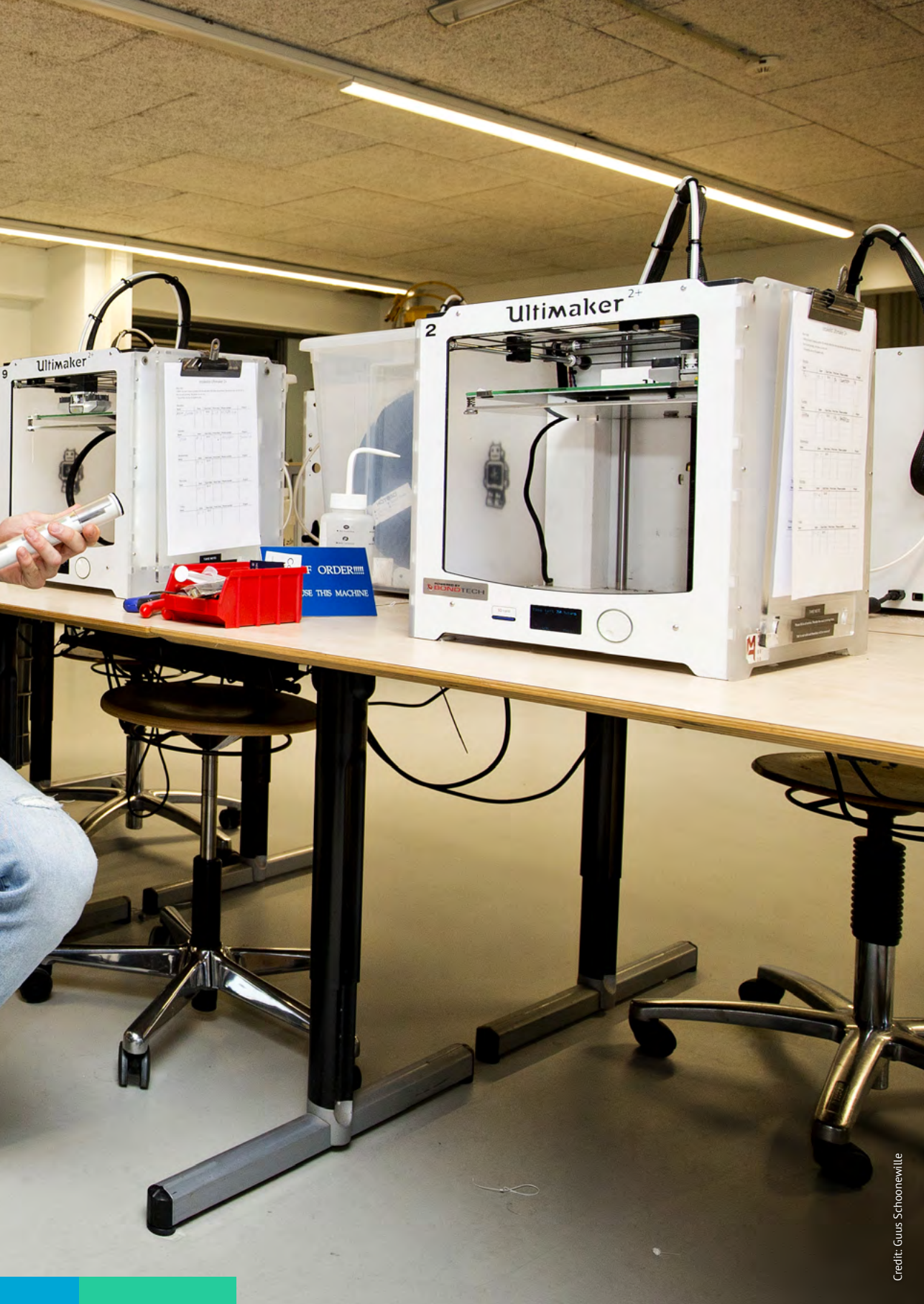
Consumers acknowledge the importance, but...

Many consumers acknowledge the importance of repair as a means to live more sustainably. Still, the vast majority continues buying new products. That is not only because of wanting something new, but often because of the negligible price difference between repaired and new products.

Obstacles and solutions

By far the biggest challenge is that the costs of repair are too high. It lowers the consumer's willingness to opt for repair. It also limits the effectiveness of the recent EU proposal which mandates that companies offer repair options if the cost of replacement exceeds the cost of repair. Techniek Nederland suggests tax measures as a solution, such as reducing the VAT for spare parts and for any repair-related labour.

Manufacturers also have an important role in reducing the high costs of repair. If they design their products to be easily repairable, it will significantly lower the costs for repair companies. This is one of the aims of the 'Promoting Repair of Goods, a Right to Repair' proposal of the European Commission, of which Techniek Nederland is a strong advocate. Together with a reduced VAT rate for spare parts and repair labour, this will certainly make repair a more appealing option, for companies *and* consumers.



Credit: Guus Schoonewille

Further Reading

#1 Repairability as a driver for the circular economy

De Fazio F., C. Bakker, B. Flipsen, R. Balkenende (2021) The Disassembly Map: a new method to enhance design for product repairability. Journal of Cleaner Production 320

Bocken, N.M.P., I. de Pauw, C. Bakker, B. van der Grinten (2016) Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering 33 (5), 308-320

Bakker, C.A., Feng Wang, Jaco Huisman, Marcel den Hollander (2014) Products that go round: exploring product life extension through design. Journal of Cleaner Production, 69, 10-16

Bakker, Conny, Ed van Hinte and Yvo Zijlstra (2022) Design for Sustainability Survival Guide. Bis Publishers, Amsterdam

#2 René Repasi is a proponent of the right to repair, both as a politician and as an academic

EU press release with referrals: Right to repair: Commission introduces new consumer rights for easy and attractive repairs

#3 The new right to repair: a bold move that leaves room for improvement

A.G. Castermans (with C.J.W. Baaij, Utrecht University), The Potential of Contractual Assurances to Advance Supply Chain Due Diligence Working Paper / EUI Robert Schuman Centre for Advanced Studies Global Governance Programme no. RSC 2023/28. San Domenico di Fiesole (FI): European University Institute, Robert Schuman Centre for Advanced Studies

A.G. Castermans (with C.J.W. Baaij, Utrecht University), De metrologie van het burgerlijk recht, Nederlands Tijdschrift voor Burgerlijk Recht 2022/10, p. 77-82

A.G. Castermans (with H.B. Krans, Leiden University) Artikelsgewijs commentaar ad titel 7.1 koop (art. 7:1 – art. 7:50i), in: H.B. Krans et al (Eds.) *Burgerlijk Wetboek. Tekst & Commentaar*, Deventer 2022: Wolters Kluwer. 3135-3210.

V. Mak, A Primavera for European consumer law: re-birth of the consumer image in the light of digitalisation and sustainability, Journal Of European Consumer And Market Law 2022, 11(3), p. 77-80

V. Mak (and E. Terryn, KU Leuven), Circular Economy and Consumer Protection: The Consumer as a Citizen and the Limits of Empowerment Through Consumer Law, Journal of Consumer Policy: Consumer Issues in Law, Economics and Behavioural Sciences 2020, p. 227-248

#4 Making a profit when repair is the norm: it is possible

Kennedy, S., & Linnenluecke, M. K. (2022). Circular economy and resilience: A research agenda. Business Strategy and the Environment, 31(6), 2754-2765

Grewatsch, S., Kennedy, S., & Bansal, P. (2021). Tackling wicked problems in strategic management with systems thinking. Strategic Organization

Kennedy, S., & Bocken, N. (2020). Innovating business models for sustainability: An essential practice for responsible managers. Research handbook of responsible management (pp. 640-653). Edward Elgar Publishing

Kennedy, S., Whiteman, G., & van den Ende, J. (2017). Radical innovation for sustainability: The power of strategy and open innovation. Long Range Planning, 50(6), 712-725

#5 Life cycle analysis is a driver for circular production, businesses, and policies

Advisory Report Repair Promotion (2022), Social and Economic Council of the Netherlands

Circular by design – Products in the circular economy (2017) European Environment Agency, Report No 6/2-17

Zink T, Geyer R. Circular economy rebound. Journal of industrial ecology. 2017 Jun;21(3):593-602

Websites: The Restart Project (therestartproject.org), The Circular Design Guide circulardesignguide.com) en True Price (trueprice.org)

#6 Disassembly: an essential enabler for repair

Bolanos Arriola, J., van Oudheusden, A. A., Flipsen, B. & Faludi, J. (2022). 3D Printing for Repair Guide. 1 ed. Delft: HollandRidderkerk. 48 p.

Flipsen, B., Bakker, C. A. & de Pauw, I. C. (2020. Hotspot Mapping for product disassembly: A circular product assessment method. Electronics Goes Green 2020+ (EGG): The Story of Daisy, Alexa and Greta. Schneider-Ramelow, M. (ed.). Berlin, 8 p.

De Fazio, F., Bakker, C., Flipsen, B. & Balkenende, R. (2021). The Disassembly Map: A new method to enhance design for product repairability. In: Journal of Cleaner Production. 320, p. 1-12 12 p., 128552.

Flipsen, B., Huisken, M., Opsomer, T. & Depypere, M. (2019). Smartphone Reparability Scoring: Assessing the Self-Repair Potential of Mobile ICT Devices. PLATE 2019: Product Lifetimes And The Environment. European Union, 10 p.

Flipsen, B., Bakker, C. & van Bohemen, G. L. A. (2016). Developing a Reparability Indicator for Electronic Products. Proceedings of Electronic Goes Green 2016+ : Inventing shades of green. Fraunhofer IZM Berlin, p. 1-9 9 p.

#7 Beyond repair: design strategies that extend the useful lifetime of products

Dangal S, Faludi J, Balkenende R. Design Aspects in Repairability Scoring Systems: Comparing Their Objectivity and Completeness. Sustainability. 2022; 14(14):8634

Arcos, B. P., Dangal, S., Bakker, C., Faludi, J., & Balkenende, R. (2021). Faults in consumer products are difficult to diagnose, and design is to blame: A user observation study. Journal of Cleaner Production, 319, 128741

#8 Changing consumer repair behaviour through design

Consumer wants to be able to repair washing machine themselves, ILT, Dutch Ministry for Infrastructure, 28/2/2023

Renske van den Berge, Lise Magnier and Ruth Mugge (2021) *T*oo good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention, Current Opinion in Psychology 2021 39:66-71

L. Magnier, R. Mugge (2022), Replaced too soon? An exploration of Western European consumers' replacement of electronic products, Resources, Conservation & Recycling, October 2022, Volume 185

#9 Repair and education: not the hardest part of the transition

Bakker, Conny, Marcel den Hollander, Ed van Hinte and Yvo Zijlstra (2016) Products that Last; product design for circular business models. Bis Publishers

Marcel den Hollander (2023) *Designing and producing for value retention in a circular economy* (Dutch), Rotterdam University of Applied Sciences Publishing House – book en public lesson.

The CIRCO-programma, hoger onderwijs curriculum kit.

#10 Repair as a creative force: lessons from the cultural world

Zapata Campos, María José, Patrik Zapata and Isabel Ordoñez (2020) Urban commoning practices in the repair movement: Frontstaging the backstage. Environment and Planning A: Economy and Space

Platform 21's repair Manifesto: platform21.nl/page/4360/en.html

The Repair Cafe network: repaircafe.org/en/visit/

Colophon

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The complete white paper, in English and in Dutch, can be downloaded at leiden-delft-erasmus.nl.

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Prof. dr. Ruud Balkenende, prof. dr. Conny Bakker, dr. Elise Blondel and dr. Yumiko Henneberry.

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Senay Boztas, Merel Engelsman (Simplifaai), Katja Hoiting and Hans Wetzels.

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