CIRCULAR
ECONOMY
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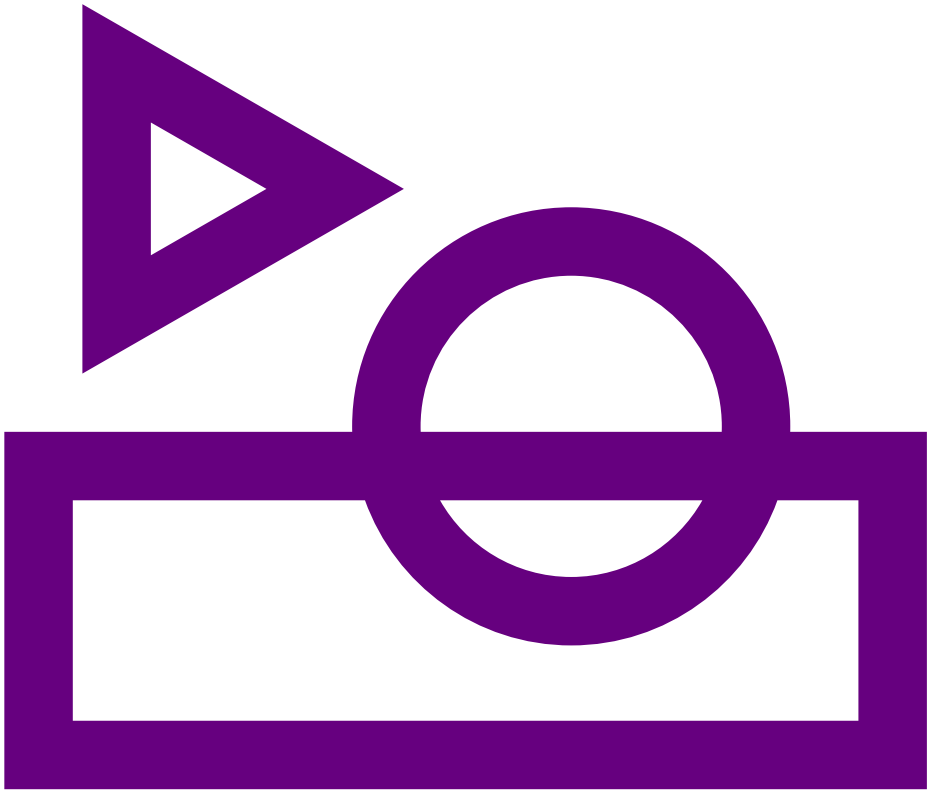

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URBAN PRODUCTS SYSTEM SUMMARY

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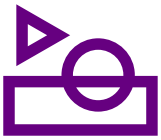

URBAN PRODUCTS SYSTEM

In a thriving city, residents and businesses have access to key consumer products that enable them to work, create, communicate, and have a high quality of life. However, current linear practices in production and consumption lead to the depletion of finite resources, high volumes of waste generation, the underutilisation of products and materials, and negative environmental and societal impacts along the entire supply chain and the exclusion of low-income groups.

Industry innovations, particularly those related to digital technologies, such as digital manufacturing and big data (known as the Fourth Industrial Revolution), are leading to greater efficiency. However, as long as the challenges of the current product production and consumption system are not addressed, these new technologies will merely buy us a bit of extra time. As urban populations grow, so will the pressure on cities to solve these imperative challenges.

DRIVERS FOR CHANGE

75%

75% of municipal solid waste consists of discarded consumer goods; of which **80%** is burned, landfilled or dumped due to poor design and/or lack of end-of-life collection options[1]

Up to **20%** of municipal budgets are spent on waste management[2]

Globally, customers miss out on up to **USD 460 billion** each year by throwing away clothes that they could continue to wear[3]

49 Mt of e-waste, worth USD 63 billion, are generated globally each year, of which only **20%** is collected and recycled under appropriate conditions[4]

80%

80% of household items are used less than once a month[5]

19% of European households' energy consumption is used for lighting, electrical appliances, and cooking[6]

In **2015**, CO2 emissions from textiles production totalled **1.2 billion tonnes** of CO2 equivalent, more than the total emissions of all international flights, and maritime shipping combined[7]

More than **80%** of a product's environmental impact is determined at the design stage

HOW CAN A CIRCULAR ECONOMY APPROACH ADDRESS THESE CHALLENGES?

Integrating circular economy principles into every stage of the urban products system can lead to a wide range of benefits. This includes reducing virgin material consumption, eliminating waste and toxins, maximising product utilisation, improving product designs and services, lowering market entry barriers for businesses, and enabling wider access to products.

Now is the time to act. By 2025, 1.8 billion people will join the global consuming class and directly fuel further linear resource consumption, unless changes are made.[8] A digital revolution in the urban products system, steered by a circular economy approach that targets design, business models, and resource management, could foster prosperity in the long term and alleviate the current negative impacts of consumption.

"The circular economy is a practical response to the main challenges of our time. As a true societal project, it carries an ambition: to develop an economy that enables individuals to joyfully reclaim their forgotten ability to create the riches they need through initiatives. (...) As a low-environmental-impact economy, it promotes new forms of production and consumption, as well as sociability, while opening up avenues for the creation of jobs that are sustainable and cannot be offshored."

Anne Hidalgo, Mayor of Paris,
Paris Circular Economy Roadmap
(2017)

SUMMARY

PHASE	EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITY
PLANNING	1. Supporting and incentivising better production (upstream) 2. Providing resource management infrastructure (downstream)
DESIGNING	1. Designing for reuse and multiple cycles 2. Designing to support efficient operation and maintenance 3. Designing in supply chain and product transparency 4. Open-source design to accelerate innovation, uptake, and customisation
MAKING	1. Sourcing locally abundant materials 2. Aligning digital manufacturing with circular economy principles 3. Increasing the distribution of manufacturing in line with circular economy principles
ACCESSING	1. Accessing products through product-as-a-service business models 2. Accessing pre-owned products through peer-to-peer models
OPERATING AND MAINTAINING	1. Empowering repair initiatives to extend product cycles 2. Refurbishing products for reuse

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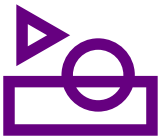
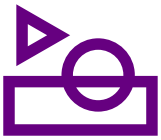


SUMMARY

PHASE	EXAMPLES OF BENEFITS	
PLANNING	**Reducing material costs:** Circular opportunities for fast-moving consumer goods could be as much as USD 700 billion per annum in material savings.	ECONOMIC PRODUCTIVITY
DESIGNING	**Saving households money:** In Europe, ecodesign and energy labelling is estimated to result in important economic savings for end-users. For example, around EUR 100 billion per year in 2020 through lower utility bills, which is equivalent to annual household savings of up to EUR 500.[9]	COMMUNITY AND SOCIAL PROSPERITY
MAKING	**Reducing CO2 emissions in the textiles industry:** For the Chinese textiles industry, automation and 3D printing, water and energy-efficiency practices and textile recycling would reduce CO2 emissions in Chinese cities by 200 million tonnes by 2040 compared with the current development path.[10]	HEALTH AND ENVIRONMENT
ACCESSING	**Reducing need for new products by renting clothing:** Per renter per year, online rental of clothes can result in 14 fewer garments being produced and disposed of, equivalent to net water savings of 37 m3 and net material savings of USD 38 per person.[11]	RESOURCE USE
OPERATING AND MAINTAINING	**Creating jobs in electronics refurbishment:** Refurbishing 1,000 tonnes of electronics creates 13 times more jobs than recycling the same amount.[12]	JOBS, SKILLS AND INNOVATION



ENDNOTES

1 Ellen MacArthur Foundation, *Towards the circular economy: opportunities for the consumer goods sector* (2013) pp. 14, 86

2 World Bank, *What a waste 2.0: a global snapshot of solid waste management to 2050* (2018) p. xil

3 Ellen MacArthur Foundation, *A new textiles economy: redesigning fashion's future* (2017) p. 73

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5 Wharton, University of Pennsylvania & Rubicon, *How green is the sharing economy?* (11 December 2015)

6 Eurostat, *Energy consumption in households* (2018)

7 Ellen MacArthur Foundation, *A new textiles economy: redesigning fashion's future* (2017) p. 20

8 McKinsey, *Starting at the source: sustainability in supply chains* (2016); D. Moore, *Growing middle class sees increase in global resource consumption*; Chartered Institution of Wastes Management (CIWM) (21 July 2016)

9 European Commission, *The ecodesign directive (2009/125/EC) European implementation assessment* (2017) p. 9

10 Ellen MacArthur Foundation, *The circular economy: opportunity for urban and industrial innovation in China* (2018) p. 101

11 Ellen MacArthur Foundation, *Towards the circular economy: opportunities for the consumer goods sector* (2013) p. 61

12 Ovam & Summa Circular Economy Policy Research Centre, *Employment impact of the transition to a circular economy: literature study* (2018) p. 22

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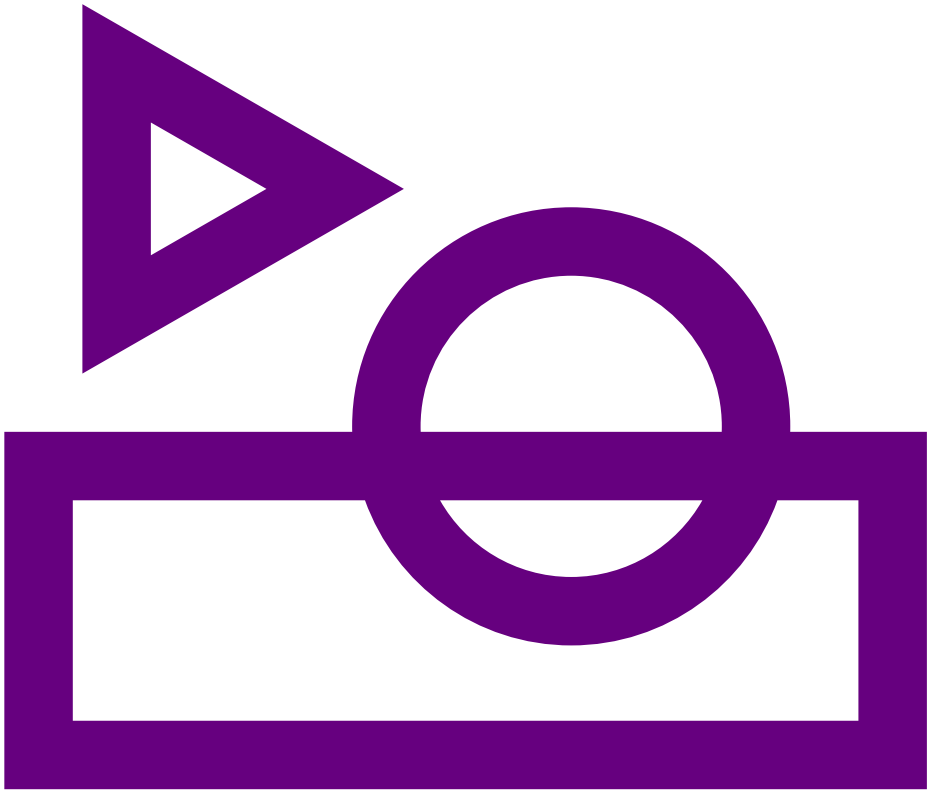

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PLANNING FOR PRODUCT INNOVATION AND CIRCULAR MATERIAL FLOWS

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Household goods tend to end up in municipal waste streams, where their value is lost and where they create a strain on public budgets. To address this at city level, both upstream and downstream policy measures are needed. To ensure effective resource consumption and the elimination of waste in cities, local material loops and flows must be created through two interrelated city-scale measures that address the entire product life cycle:

1. Upstream: Enabling and incentivising better production through business support and advisory services that focus on design and business development.

2. Downstream: Providing resource management infrastructure that facilitates services such as collection, sorting, reuse, and recycling.

CASE FOR CHANGE

75% of municipal solid waste is discarded consumer goods of which **80%** is burned, landfilled or dumped due to poor design and/or the lack of end-of-life collection options[1]

Solid waste management alone leads to **5%** of global CO_2 emissions[2]

Up to **20%** of municipal budgets are spent on waste management[3]

32% of plastic packaging ends up as litter outside waste collection systems [4]

One garbage truck of textiles is landfilled or incinerated every second,[5] representing a lost opportunity of more than **USD 100 billion** annually[6]

E-waste, worth **USD 107 billion**, is generated globally each year, of which only **20%** is collected and recycled under appropriate conditions[7]

"The aspiration to replace one-way products with goods that are 'circular by design' and create reverse logistics networks and other systems to support the circular economy is a powerful spur to new ideas. The benefits of a more innovative economy include higher rates of technological development; improved materials, labour, and energy efficiency: and more profit opportunities for companies."

Ellen MacArthur Foundation, Towards the circular economy: opportunities for the consumer goods sector (2013)

EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITIES

Supporting and incentivising better production (upstream)

Product design decisions and new business models are key to eliminating waste and the underuse of products. For example, the way a product is designed might make it easier to repair – keeping it in use and out of landfill. A city's policies and activities related to business sutpport and economic development can be used to incentivise these methods. Support for skills and training can also help ensure that digital manufacturing, remanufacturing, and repair expertise exists.[8]

Providing resource management infrastructure (downstream)

While appropriate product design is key to enabling local material loops, there is also a need for the right resource management infrastructure to be put in place. This includes standardised collection and sorting schemes, reverse logistics services, as well as local sorting and processing facilities that can recover and redistribute materials and products for further use. Sorting infrastructure can be supported by innovations in robotics and artificial intelligence that can increase rates of recovery and purity of secondary materials.[9]

RELEVANT CASE EXAMPLES

Upstream: Circular economy business support programme in London

Advance London is a circular economy business support programme that helps qualifying SMEs develop circular economy solutions. Run by the London Waste and Recycling Board, the programme includes advisory services, an investment programme, and a business accelerator. Less than two years in, the programme has delivered 450 hours of support to 82 SMEs – one in three of which has secured grant, equity or loan funding within 18 months. The programme has helped to facilitate 20 product-market collaborations, which to date have generated five new circular products or services. (See *Cities case study: London*)

Upstream: "Policy (for) making" programme in Milan

Through the Manifattura Milano programme, Milan is promoting the development of local digital manufacturing and craftsmanship. The city is encouraging a new type of industry that is characterised by locally appropriate design, consumption with low environmental impact, and increasingly custom-made products, thanks to the use of new technologies such as 3D printers and augmented reality.[10] Today, Milan has more than 100 co-working spaces, ten Fab Labs and maker-spaces, incubators and business accelerators, and cultural and creative hubs – all with strong links to the city's universities.[11]

Upstream: An online marketplace for material exchanges in Austin

Austin's Material Marketplace is an online platform set up by the city to connect organisations that are looking to sell or buy used or surplus products and materials. The initiative supports the city's goal of zero waste by 2040 and is part of the Recycling Economic Development Program which aims to attract, retain, and grow zero waste businesses and create local jobs by fostering a resilient, zero waste production system.[12] (See *Cities case study: Austin*)

Downstream: Leapfrogging to advanced resource management in Ljubljana

When Slovenia joined the EU in 2004, the country had no proper waste separation and collection schemes in place. In less than ten years, the capital, Ljubljana, managed to become a frontrunner in waste management. The city leapfrogged the traditional waste management approach and developed a strong collection and sorting system that has proved that avoiding incineration, and reducing landfilling by 59% and waste generation by 15% is feasible in a very short time. Ljubljana's recycling rate is now 20 percentage points above the EU average and 10 percentage points above its 2020 targets. Ljubljana generates 10% less municipal waste than the EU average, and has one of the lowest waste management cost burdens in Europe. According to the city, political courage, community engagement, and effective communication campaigns have been key elements in Ljubljana's success.[13]

EXAMPLES OF WHAT URBAN POLICYMAKERS CAN DO

To ensure a city's economic development initiatives and resource management efforts are aligned, a **roadmap or strategy** setting out clear guidelines for how these areas should be connected can be beneficial. This could, for example, be in the city's masterplan. **Financial support** and **capacity building** measures can help stimulate the urban products system, both upstream through business programmes, and downstream through infrastructure investments. **Awareness raising** can be a powerful instrument to influence citizens' behaviour – for example, to embed new habits and encourage people to sort household waste for recycling. Cities can use **fiscal** or **regulatory measures** to incentivise or enforce better production and resource management practices.

To explore further see **Policy Levers**

EXAMPLES OF LINKS TO OTHER SYSTEMS AND PHASES

Mobility: Planning

In a circular products system, reverse logistic schemes will be key to support the circulation of goods and materials, which means that appropriate freight schemes will be required to meet increasing logistics demand.

Buildings: Planning

Increasing proximity through compact city development can support opportunities to circulate products and reduce travel distances.

EXAMPLES OF BENEFITS

ECONOMIC PRODUCTIVITY

Creating new profit potential

Collected and sorted clothing has a profit potential of around USD 1,300 per tonne.[14]

Reducing material costs

Circular opportunities for fast-moving consumer goods could be as much as USD 700 billion per annum in material savings.[15]

HEALTH AND ENVIRONMENT

Reducing the environmental impacts on cities of the electronics industry

Better recycling, higher-value end-of-use options (e.g. remanufacturing), and performance-based business models in urban China's electronics and electric appliances industries could reduce emissions of CO_2 by 24 million tonnes and of particulate matter (PM2.5) by 11% in 2030.[16]

Reducing similar impacts of the textiles industry

In Chinese cities, implementing all circular economy opportunities in textiles could have a significant impact on reducing environmental impact costs, by USD 64 billion in 2030 and USD 112 billion in 2040.

RESOURCE USE

Reducing reliance on raw materials for electronics

Better recycling, higher-value end-of-use options (e.g. remanufacturing), and performance-based business models in urban China's electronics and electric appliances industries could reduce reliance on key virgin raw materials, such as precious metals, by 14% in 2040.[17]

Increasing e-waste recovery

Circular economy resource management infrastructure, optimised using AI solutions, could enable the recovery of USD 24 billion of additional value from reused, repaired, remanufactured or recycled devices, components and materials. AI can help capture a significant part of the total e-waste market, which is estimated to be USD 107 billion.[18]

Reducing reliance on raw materials for textiles

Stimulating automation and 3D printing, water and energy efficiency, and textile recycling would decrease the need for virgin materials and other primary resources in Chinese cities, while generating USD 48 billion in savings by 2040.[19]

JOBS, SKILLS, AND INNOVATION

Creating jobs from utilisation of municipal waste

On a European scale, reuse can create significant local employment: on average, 80 jobs could be created for every 1,000 tonnes of collected municipal solid waste. Europe-wide, 200,000 jobs could be created if 1% of total EU municipal solid waste were to be collected and sorted.[20]

Creating jobs and training in the collection and sorting of electronics

15 jobs and 110 training opportunities could be created for every 1,000 tonnes of electronics collected and sorted for reuse. In Europe alone this could amount to between 55,000 and 93,500 jobs.[21]

Creating jobs and training in textiles collection and sorting

Around 20 jobs could be created for every 1,000 tonnes of textiles collected and sorted for reuse, adding up to 120,000 jobs in Europe.[22]

Creating jobs in packaging waste management

In France, the sorting, collection, and recycling of packaging could generate more than 10,000 jobs.[23]

Creating jobs in packaging deposit-return-schemes (DRS)

The introduction of a DRS for beverage containers in the UK could generate between 3,000 and 4,300 jobs in collection and processing as well as an additional increase in the number of higher-skilled jobs.[24] In Germany, expansion of the DRS to all drinks containers could create 27,000 jobs.[25]

Generating higher salaries

Recycling a tonne of solid waste will pay USD 101 more in salaries and wages than disposing of it in landfill.[26]

The main driver is increased water recycling and treatment, which contributes 60% of the 2040 cost reductions.[27]

COMMUNITY AND SOCIAL PROSPERITY

Increasing access by reducing cost

By 2040, China's urban electronics and electric appliances industries, upstream and downstream circular economy measures could reduce total cost of access by nearly 14% compared with the current development path. This could therefore increase access to these goods for lower-income groups.[28]

ENDNOTES

1 Ellen MacArthur Foundation, *Towards the circular economy: opportunities for the consumer goods sector* (2013) pp. 14, 86

2 Excluding transportation to and from sites and the emissions embedded in the waste products. World Bank, *What a waste 2.0: a global snapshot of solid waste management to 2050* (2018) p. xi

3 Ibid., p. xil

4 Ibid., p. xi

5 Ellen MacArthur Foundation, *A new textiles economy: redesigning fashion's future* (2017) p. 37

6 Ibid. (2017) p. 91

7 Ellen MacArthur Foundation, *Circular consumer electronics: an initial exploration* (2018) p. 5; Ellen MacArthur Foundation/ Google, *Artificial intelligence and the circular economy* (2019) p. 27

8 Ovam & Summa Circular Economy Policy Research Centre, *Employment impact of the transition to a circular economy: literature study* (2018) p. 23; McKinsey & Company, *Acquiring the capabilities you need to go digital*, (March 2015)

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10 M. Bianchini and S. Maffei, *'Make in Milan'*, in Fab City, *The mass distribution of (almost) everything* (2018) p. 188, City of Milan, *Manifattura 4.0: linee guida,* milanosmartcity.org (n.d.)

11 A. D'Elia, *Municipality as a platform: the case of Manifattura Milano,* Linköping University Electronic Press (2018)

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15 Ibid. (2013) p. 9. Including food and beverages which otherwise is out of the scope of this project. To learn more about the role of food in cities see the Ellen MacArthur Foundation's project Circular Economy for Food in Cities.

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22 Ibid.

23 Mairie de Paris, *Paris circular economy plan* (2017) p. 6

24 D. Hogg *et al.*, *From waste to work: the potential for a deposit refund system to create jobs in the UK,* Campaign to Protect Rural England (2011) p. 29

25 Mairie de Paris, *Paris circular economy plan* (2017) p. 6

26 Ovam & Summa Circular Economy Policy Research Centre, *Employment impact of the transition to a circular economy: literature study* (2018) p. 23

27 Ellen MacArthur Foundation, *The circular economy opportunity for urban and industrial innovation in China* (2018) p. 100

28 Ibid., p. 113

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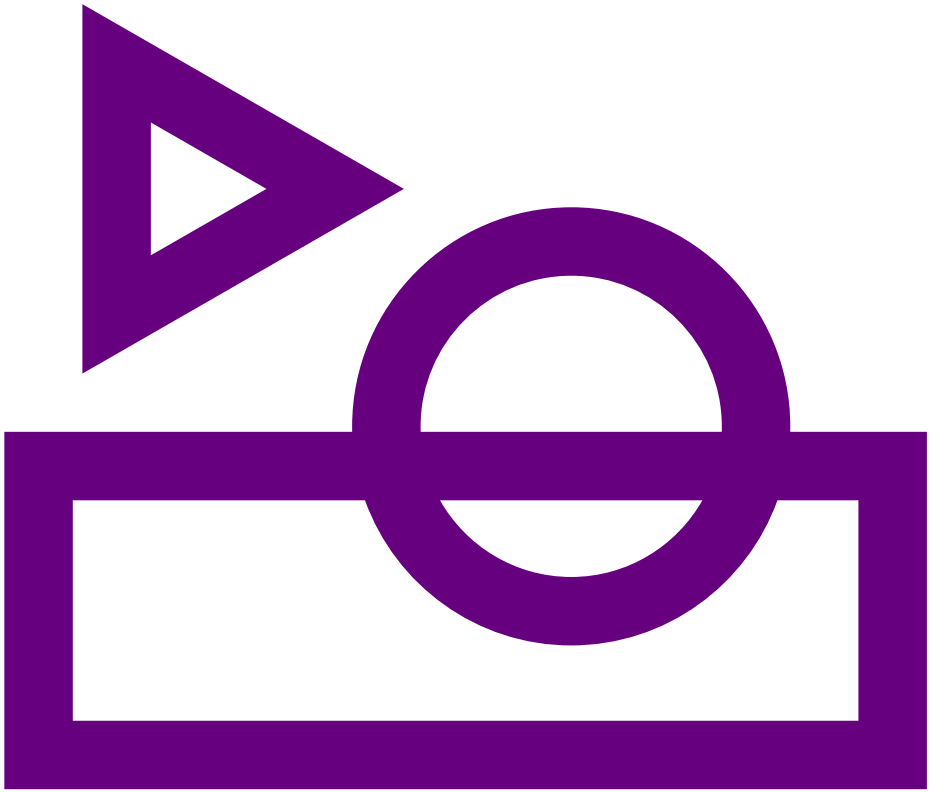

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DESIGNING FOR REUSE AND CIRCULATION OF PRODUCTS AND MATERIALS

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Decisions made in the design phase of a product can significantly influence how circular it is. For example, a phone can be designed to be easily repaired and its components upgraded, and a sofa can be made from locally available, non-harmful materials. Today, many products are designed to meet customer needs during the first use phase, but not thereafter. This impacts the wider system in which they are made, used, and disposed of. Combining a user-centric and holistic approach to product design is key to creating an effective urban products system that follows circular economy principles. New solutions such as artificial intelligence, block-chain, open-source, and cloud designing can further accelerate innovation within product and material design.

THE CASE FOR CHANGE

80%

More than 80% of a product's environmental impact is determined at the design stage[1]

19% of European households' energy consumption is used for lighting, electrical appliances and cooking. This could be reduced through better product design[2]

30% of plastic packaging will never be reused or recycled due to poor design[3]

2.5 Mt of toxins are generated from e-waste each year[4]

0.5 Mt of plastic microfibres are released into the ocean annually from the washing of textiles. This could be avoided with different material choices[5]

In the fashion industry, mismanagement of chemicals in the workplace is estimated to cost **EUR 7 billion** a year by 2030 in illness and early mortality[6]

"When you realise that the economy is designed, then of course you understand that it can be redesigned."

Chris Grantham, Executive Portfolio Director, IDEO London (2018)

EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITIES

Designing for reuse and multiple cycles

With the introduction of performance-based business models, where the customer pays for the use of the product rather than the product outright, there is an increased incentive to design products of a higher quality that last longer. This means that product design seeks to enable repair, upgrading, component reuse, material sorting, and recycling by ensuring that the product is easy to take apart and does not contain materials that can be problematic in further use. Timeless design can also prolong the use cycle. Modular design principles that ease repair or upgrade (for example when a better component is developed) can minimise disruption and increase the product's overall resource efficiency. Products that are virtualised, or designed for 3D printing and local production, can reduce material inputs and freight transport. See also *Products: Making* or *Mobility: Accessing.*

Designs that support efficient operation and maintenance

It is important for products that consume energy and/or water during use to be designed to make the most of these inputs, leading also to reduced operational costs. Designing products to include built-in smart meters and sensors can help users to monitor and optimise energy and/or water consumption. Sensors can also predict maintenance needs before a product breaks.

Designing in supply chain and product transparency

New blockchain-based information technologies and digital watermarking (such as QR codes or chemical markers) are enabling designers and makers to provide full product and material transparency along the supply chain.[7] Users of this information can include, for example, a customer who wants to avoid certain allergens, a company that wants to repair the product, or a recycler that wants to sort and resell materials after use. This type of transparency means that products can become 'bmaterial banks' that can support more effective production, use, and end-of-use phases.

Open-source design to accelerate innovation, uptake, and customisation

Open-source design can accelerate innovation and scale the uptake of circular economy solutions. Such design also supports the uptake of distributed manufacturing (enabled by digital technologies) by allowing individuals and makers to gain access to circular economy designs and apply them. Open design platforms can connect designers, makers, and users across geographies, enabling them to share best practice while allowing them to adapt product designs to local conditions relating to, for example, user needs, available materials, and municipal recycling schemes.

EXAMPLES OF WHAT URBAN POLICYMAKERS CAN DO

By reshaping **public procurement** criteria, city governments can support the emergence of circular product designs. For example, by adding specifications on the use of non-harmful materials and on extended producer responsibilities.

Capacity building programmes for innovators and entrepreneurs on circular economy and design in relation to the local context can help stimulate innovation.

Awareness raising about the benefits of circular designs and local opportunities can support the uptake of new products and business models.

To explore further see **Policy Levers**

EXAMPLES OF LINKS TO OTHER SYSTEMS AND PHASES

Products: Making Design considerations, such as material choice and how to support distributed manufacturing and local material flows, can improve the overall quality and applicability of the design.

Products: Accessing Product-as-service business models go hand-in-hand with high-quality product design, as businesses can benefit from reduced virgin material consumption, remanufacturing opportunities, and high recyclability.

CASE EXAMPLES

Modular headphone design for service-based business models

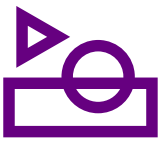
On a global scale 15,000 tonnes of headphones are discarded every year. To address the issue Gerrard Street has designed high-quality headphones that are modular and easy to disassemble for repair, refurbishment, and upgrade. The headphones are offered on a subscription basis allowing customers to get them upgraded or repaired at no additional cost. Since 85% of the headphone components are reused, Gerrard Street reduces its need for virgin materials when creating new headphones, and customers get access to a high-quality product that is affordable and has a high level of service.[8]

Packaging designed for reuse

Splosh and Replenish are companies that sell concentrated household cleaning products through a system where bottles can be used repeatedly and refilled with sachets of concentrated liquid. Their packaging is reusable and designed for long use, which results in reduced energy consumption, plastic waste, and CO_2 emissions by 80–90% compared to single-use bottles. By selling concentrated sachets that can be diluted with local tap water to create cleaning liquids, they also avoid the need to transport water over great distances.[9] RePack offers a reusable packaging service for retailers that can last at least 20 cycles. The packaging can be folded down to a letter size and returned in the post for reuse. A reward system encourages the customer to return the packaging, while strengthening the relationship between customers and retailers.[10]

Procuring furniture designed for disassembly

In 2012, Denmark's central procurement agency (SKI) established a four-year framework for sustainable office furniture for more than 60 municipalities. Technical specifications were based on environmental requirements of the Nordic Swan eco-label, and included requirements on the chemicals used in the manufacturing, treatment, coating or dyes used, and the possibility of separation and recovery of materials at end-of-use. Wood and wood-based materials were also required to come from legally harvested timber, and at least 70% of this had to be either recycled or verified as sustainable timber. By using this framework approach, savings of up to 26% compared to market prices were achieved, and the market for circular furniture products was broadened.[11]



Open source and flexible product design

Bang & Olufsen's open-source speaker solution, BeoCreate, is specifically designed to enable customers to upgrade old Bang & Olufsen speakers. BeoCreate comes with instructions on how to 'hack' and adapt the speakers. Through this combined product and service model old speaker components are kept in use while Bang & Olufsen gain useful insights on innovation from their users.[12]

EXAMPLES OF BENEFITS

ECONOMIC PRODUCTIVITY

Reducing operation costs

The most energy-efficient washing machine and electric oven designs can save the user EUR 230–250 over the lifetime of the product.[13]

Reducing product return costs

Greater product quality can ensure longer product life and can benefit retailers by reducing product returns due to failure. Product returns currently cost UK retailers and brands up to GBP 400 million every year.[14]

JOBS, SKILLS, AND INNOVATION

Supporting growth, jobs, and innovation

The European Ecodesign Directive (framework legislation that governs European product design) is expected to generate EUR 55 billion in revenue per year for industry, producing up to 800,000 additional jobs and will have a significant overall positive effect on economic growth, investment, and innovation.[15] It also ensures a level playing field in the market for companies that are developing or using better design solutions.[16]

COMMUNITY AND SOCIAL PROSPERITY

Saving households money

In Europe, ecodesign and energy labelling is estimated to result in important economic savings for end-users. For example, around EUR 100 billion per year in 2020 through lower utility bills, which is equivalent to annual household savings of EUR 500.[17]

HEALTH AND ENVIRONMENT

Reducing health risks

The negative health impacts on workers in the fashion industry has been estimated at EUR 7 billion each year by 2030. However, safe and non-toxic material inputs would reduce these health risks for the workers as well as the people wearing the textiles.[18]

Reducing CO_2 emissions

Carrying out a range of simple, already feasible design options to extend the lifetime of laptops, printers, and washing machines in the EU could lead to savings in greenhouse gas emissions of over 1 million tonnes per year – the equivalent of taking 477,000 cars off the road for a year.[19]

RESOURCE USE

Saving energy and water

With more efficient washing machines, Europe would see annual savings of 1.5 TWh of electricity and 100 million m^3 water by 2020.[20]

Increasing energy security

The European Ecodesign Directive and Energy Labelling Regulation is estimated to generate around half of the EU's energy savings target for 2020 (around 175 Mtoe primary energy per year by 2020) and reduce fossil fuel imports by 30%.[21]

Increasing product life

Good design can make even smaller products more durable, for example the longest lasting light bulb has been in use since 1901.[22]

Reducing reliance on raw materials for textiles

Dutch Awearness has developed a 100% recyclable textile fabric, which can offer energy and water savings of 64% and 95% respectively, while cutting down on raw material demand by 61% compared to standard virgin textiles.[23]

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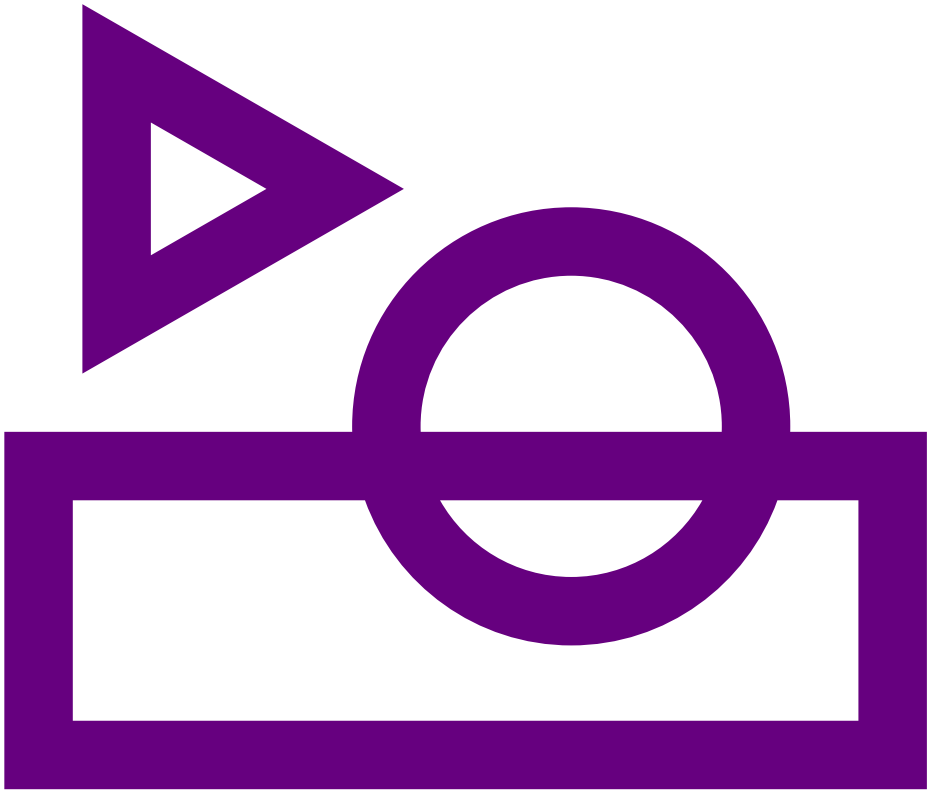
CIRCULAR ECONOMY IN CITIES



MAKING PRODUCTS WITH TECHNIQUES THAT ARE DIGITALLY ENABLED AND INCREASINGLY LOCAL

ELLEN MACARTHUR FOUNDATION

Production processes, while often efficient – with supply chains spanning the globe – are inherently harmful due to the pollution and waste they generate. Transition to a circular economy production system can provide many solutions to these challenges, particularly when harnessing new digital technologies. The emerging Fourth Industrial era, which is characterised by disruptive digital technologies (e.g. Internet of Things, virtual reality, robotics, and artificial intelligence), offers exciting new production opportunities that can, if used well, support circular economy practices and thereby improve our use of materials.

THE CASE FOR CHANGE

29% of US greenhouse gas emissions result from goods produced in the US[1]

In 2015, CO^2 emissions from global textiles production totalled **1.2 billion tonnes** of CO^2 equivalent – more than combined total emissions of all international flights and maritime shipping[2]

80%

The typical supply chain of a consumer goods company generates a far greater negative environmental impact than its own operations – often accounting for more than **80%** of CO^2 emissions and more than **90%** of the impact on air, land, water, biodiversity, and geological resources[3]

"3D printing won't be an innately green manufacturing technology unless we actively seek to make it one. If we can tap into 3D printing's unique capabilities and invent greener printing materials, we will reap environmental benefits in the form of shorter supply chains and a new generation of optimised products."

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EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITIES

Sourcing locally abundant materials

Selecting renewable and non-toxic materials that are locally abundant (including recycled materials and industrial by-products) offers a key opportunity to create local material loops.

Aligning digital manufacturing with circular economy principles

Digital manufacturing (such as 3D printing) and artificial intelligence create exciting new product production opportunities. Manufacturers can produce goods more efficiently with less waste, customise their products to meet unique needs, and shorten their supply chains by printing parts or products on-demand and near their customers.[4] Crucial to taking advantage of these technologies is ensuring that the materials chosen are safe to cycle (e.g, non-toxic) and designed to cycle (e.g, be reused and recycled). Consumer goods companies can also create supply chain transparency by using blockchain-based solutions, which will increase visibility of choices made during the production process.[5] (See *Products: Designing*)

Increasing the distribution of manufacturing in line with circular economy principles

The term distributed manufacturing covers the decentralisation of production in dispersed, localised production facilities. These facilities can be centrally owned or small, independent enterprises. Desk and office-sized digital machine tools (e.g, 3D printers and laser cutters), backed up by digital knowledge sharing, have made small-scale production possible commercially – giving life to the likes of 'the maker movement', and 'fab labs'.[6] When makers follow circular economy principles in their designs and material sourcing, these distributed manufacturing networks can have a powerful impact on the urban product system (See *Products: Designing*).[7]

CASE EXAMPLES

A material recipe library to enable circular production

To create an effective closed-loop products systems, where all materials can go back into use or are returned to nature, it is important that makers use the appropriate materials. Materiom is a non-profit organisation working to support this by creating an extensive material recipe library. The library covers many types of materials including plastics, ceramics, and composites and the recipes use only biological, locally abundant ingredients that can decompose naturally and therefore stay in natural cycles. As the availability of ingredients differs from place to place, the platform is open-source, encouraging everyone to use it and contribute to it.

A joint venture to increase locally available PET recyclates for packaging

Coca-Cola has invested EUR 13 million in two strategic partnerships to increase the recycled content of its plastic bottles. The aim of this venture, called *Continuum*, is to improve the capacity for plastics reprocessing in Great Britain and France. In these countries, around half of the discarded PET plastic is not collected for recycling and much of what is collected is sent abroad for reprocessing – limiting the supply of locally available recycled PET (rPET) with which to manufacture. This joint venture ensures that the increasing demand for rPET can be met. *Continuum* in Great Britain has been operational since May 2012 and is now the biggest plastic bottle reprocessing facility in the world, producing 25,000 tonnes of food-grade rPET a year – double the amount previously produced in the country. The project saves around 33,500 tonnes of CO^2 per year – the equivalent of taking over 15,715 cars off the road – and has created 30 new skilled jobs.[8]

A global design platform for local making

Opendesk is a furniture platform that connects designers, makers, and customers. The customer can select a design on the website and then pick between a range of quotes from local independent workshops that bid to produce the order, eliminating the shipping needs. Each piece of furniture is designed by a designer in the network and consists of modular pieces that can be made on digital plywood cutters in any of the local workshops of the platform. Currently, Opendesk operates in 16 cities across the world and is experimenting with creating closer links with local material suppliers. The model reduces the number of intermediaries and the length of the supply chain while increasing pay for designers and makers and giving customers access to high-quality furniture at more affordable prices.[9]

EXAMPLES OF WHAT URBAN POLICYMAKERS CAN DO

Awareness raising and **capacity building** programmes on circular economy and new distributed production methods for entrepreneurs, small companies, and community initiatives are ways in which urban policymakers can help create new skills, jobs, and innovation opportunities. A key barrier for people to set up makerspaces is the lack of affordable space.[10] Through **asset management policies**, city governments can allocate surplus city-owned space to such activities or incorporate them in existing facilities such as libraries and educational institutions.

To explore further see **Policy Levers**

EXAMPLES OF LINKS TO OTHER SYSTEMS AND PHASES

Products: Planning Effective resource management schemes that enable easy recovery and redistribution of materials and by-products are key to enabling the supply of locally appropriate materials for product manufacturing. Policies that support upstream developments, such as increasing urban manufacturing capacity, also play a role.

Products: Designing Product design decisions can be central to enabling the adoption of new production methods and the use of local materials.

Buildings: Accessing Access to affordable urban space for the making of products can play an important role in nurturing urban manufacturing capacity. Circular economy opportunities such as increased space sharing can alleviate this problem and support inter-business collaboration.

EXAMPLES OF BENEFITS

ECONOMIC PRODUCTIVITY

Reducing manufacturing costs

Studies suggest that 3D printing can reduce manufacturing costs by USD 170–593 billion by 2025 depending on the rate of uptake.[11]

Generating cost savings in the textiles industry

Stimulating automation and 3D printing, water and energy efficiency, and textile recycling, in China's urban textiles industry could decrease the need for virgin materials and other primary resources, while generating CNY 0.3 trillion (USD 48 billion) in savings by 2040.[12]

Increasing urban economic resilience

Greater diversification and localisation of production and feedstock supply can support cities and their inhabitants in becoming more self-sufficient and resilient to changes in global markets.[13]

JOBS, SKILLS, AND INNOVATION

Lowering barriers to market entry

Distributed manufacturing lowers barriers to market entry by reducing the amount of capital required to build the first prototypes and products.[14]

Increasing citizen-centric innovation

Access to affordable digital fabrication tools and expert knowledge, combined with involving users in co-creation, can provide new sources of innovation that derive from citizens.[15]

Accelerating prototyping and development

3D printing for injection-moulding tools helped Unilever to cut lead times for prototypes by 40%.[16]

COMMUNITY AND SOCIAL PROSPERITY

Increasing social cohesion

Distributed production in the form of common maker-spaces, and peer-to-peer learning can support social cohesion and inclusion as less affluent actors have increased opportunities to sustain themselves and grow businesses.[17]

HEALTH AND ENVIRONMENT

Decoupling production from CO^2 emissions

It is estimated that, if 3D printing was applicable to larger production volumes in consumer products, it has the potential to decouple energy and CO^2 emission from economic activity.[18]

Reducing CO^2 emissions in the textiles industry

Stimulating automation and 3D printing, water and energy efficiency, and textile recycling, in China's urban textiles industry could would reduce CO^2 emissions in Chinese cities by 200 million tonnes by 2040 compared with the current development path.[19]

Decreasing embedded freight kilometres

Distributed manufacturing can reduce embedded freight kilometres as digital information is shipped over the web rather than physical products being transported in freight vehicles. In addition, if raw materials are sourced locally, freight is further reduced.[20]

RESOURCE USE

Reducing energy consumption

The energy demand of manufacturing polymer products can be reduced by 41–64% with existing low-cost open-source 3D printers.[21]

Supporting resource efficiency

Additive manufacturing can be a more resource-efficient option because it enables the on-demand production of spare parts, and the reduction or elimination of inventory, production waste, and transportion costs.[22]

Increasing material efficiency in electronics production

Artificial intelligence, such as automated and quality control checks, can help reduce waste in the global production of consumer electronics worth USD 8 billion.[23]

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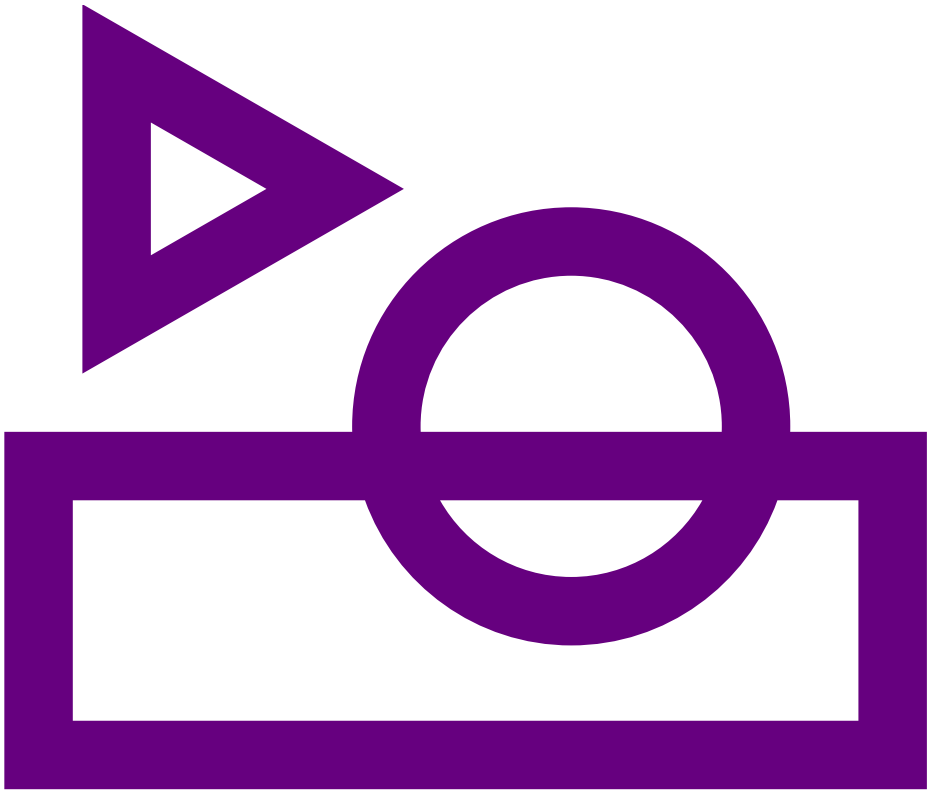
CIRCULAR
ECONOMY
IN CITIES



ACCESSING CONSUMER PRODUCTS THROUGH BETTER MEANS

ELLEN
MACARTHUR
FOUNDATION

Consumer products are frequently underutilised – often being used just a few times before being stored or discarded. This structural waste can be countered by new business models and changes in consumer habits that focus on access rather than ownership. New consumption models can make high-quality products accessible to more people and reduce the underuse and/or discarding of products. Access can be facilitated through a range of sharing and reuse models, often digitally enabled, that benefit people, business, and the health of the wider system.

CASE FOR CHANGE

A power drill is used an average of **18 minutes** in its lifetime[1]

80%

80% of household items are used less than once a month[2]

An average US household contains **USD 7,000** worth of unused items. This adds up to **USD 875 billion** worth of stuff that could be put back into the US economy alone[3]

1,000%

Self-storage has increased by **1,000%** over the past three decades[4]

By 2025, **1.8 billion people** will join the global consuming class and directly fuel further linear resource consumption, unless changes are made.[5]

70%

In China, the number of times clothes are worn on average has reduced by **70%** over the last 15 years[6]

EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITIES

Accessing products through product-as-a-service business models

New business models can offer temporary access to products rather than selling them outright through subscription and pay-per-use models. Such models can also serve more customers with a smaller stock of products. Two models are typically used: sharing and pay-per-use. These are not necessarily incompatible: for example, a product such as a washing machine can be made available to various users to share but payment is on a per-use basis. While such business models are not always new, they can now be significantly optimised through smart technology, increasing convenience and keeping much better track of the product's condition. This type of business model has an important upstream effect on the product's design as it creates a business incentive to create products that perform better for longer to enable additional revenue and reduce maintenance needs.

Accessing pre-owned products through peer-to-peer models

While the reuse market for consumer products is not a new invention, it is far from realising its full potential. Reselling pre-used items helps maximise their value and increase the affordability of products.[7] Making underused products available for use (through resale, renting or donation) is also key to decreasing demand for new products and therefore demand for resources. Online sharing platforms and peer-to-peer online resale platforms makes reuse increasingly easier. Artificial intelligence (AI) can be used to optimise these platforms' services by enabling product classifications, and dynamic pricing, by taking into consideration market conditions and product-specific characteristics such as age and brand.[8]

EXAMPLES OF WHAT URBAN POLICYMAKERS CAN DO

City governments can include specifications in **public procurement** tenders on maintenance, take-back, and reuse that support the emergence and scaling of new business models, and can lead to public finance savings and improved resource management. Through **awareness raising** and **convening** initiatives, city governments can help urban stakeholders to share, swap, lease, and donate products (such as Gothenburg's smart-map). Increased sharing and leasing will also increase the need for logistics services, which ideally will be **planned** into the city's overall mobility system to alleviate potential negative impacts such as increased congestion.

To explore further see **Policy Levers**

EXAMPLES OF LINKS TO OTHER SYSTEMS AND PHASES

Mobility: Accessing The viability of a performance-focused product model is closely linked to efficient, low-impact logistics services for the delivery, servicing, and collection of products and materials.

Products: Designing Appropriate product design is also key to ensuring the viability and attractiveness of performance-based business models.

Buildings: Planning Decluttering homes and offices, through a reduction in storage needs, can free up built space for alternative uses.

CASE EXAMPLES

Leveraging app and AI technology for instant buy-back of every purchase

Stuffstr, a London-based social enterprise, is partnering with retailers to provide instant buy-back of every item sold. Retail customers who log into their accounts on the retailer's app or website can review their purchases from the past five years, and are offered an instant buy-back price on every item, regardless of condition. Items are picked up for free the same day, and customers are paid instantly in the form of vouchers at the originating retailer as soon as the items are received. Stuffstr then resells the items through existing secondary markets, and responsibly recycles any items that cannot be resold. Stuffstr uses AI algorithms to optimise the prices being offered to ensure they never exceed the net return on the resale of the items. After conducting a successful pilot, Stuffstr and John Lewis will be launching the service more broadly with additional brands and retailers in 2019.[9]

Online and physical libraries of things

Like traditional libraries, users can borrow items at low or no cost for a defined period of time. These schemes are especially appropriate for items people use rarely, such as DIY and gardening tools, camping equipment or formal wear. In Toronto, a small non-profit tool library offers local residents access to more than 7,000 tools that are maintained and repaired by a local crew of volunteers. Many of the tools have been donated by residents who are keen to clear space in their homes.[10] Online borrowing platforms also exist, like Fat Llama, that facilitate peer-to-peer lending, with insurance for lenders that is covered by the platform.[11] Many traditional libraries are also expanding their services: in New York, office wear is lent out to people going to job interviews – combining increased access to clothing with support to get into employment.[12]

Household items as a service

Items such as clothing and furniture can be expensive investments, especially for those who need to change them frequently. That is why many new product subscription companies are experiencing significant growth. Vigga, a Danish company, offers baby and maternity clothing, that is highly durable and non-toxic, meaning it is safe, reusable, and recyclable. The company estimates that this model, where each item can be used by around 10 families before being recycled into new clothes, reduces waste by around 80%.[13] Other companies offer entire fit-outs for homes and offices. STRATA, for example, provides turnkey furniture solutions for entire rooms on a subscription basis – all optimised through modular design principles that support customisation, reconfiguration, reuse, and refurbishment.[14]

Sharing smart-map brings city together

The City of Gothenburg has, together with local residents, developed a smart-mapping tool, Smarta Kartan, which shows where residents can find things to hire, borrow, share, and swap. It is helping to bring people together, change their behaviour, reduce consumption-based carbon emissions, and inspire new services. Within six months, 10,000 inhabitants had visited the smart-map and the 100 featured initiatives identified the map as a crucial asset and contributor to their activities. By raising the visibility of the city's community resources, the smart-map has already led to more collaborations between existing sharing projects, as gaps have been identified and new ideas developed. Next on the agenda is making the map open source to allow other cities to replicate the framework.[15]

EXAMPLES OF BENEFITS

ECONOMIC PRODUCTIVITY

Creating new profit potential through clothing rental

The online rental of clothes presents an economic opportunity of ~USD 200 in operating profit per renter – greater than that offered by online retail sales.[16]

Decreasing cost of access

Increased utilisation of durable textiles will realise the greatest benefits in total cost of access. In Chinese cities, such efforts could generate USD 80 billion (CNY 0.5 trillion) in savings by 2040.[17]

HEALTH AND ENVIRONMENT

Reducing CO^2 emissions through longer use of clothes

By doubling the number of times a garment is worn, CO^2 emissions could be reduced by 44%.[18]

Reducing CO^2 emissions through printing-as-a-service models

Printing as a service in which the user pays per print and can return old ink cartridges for recycling through a smart take-back scheme, can reduce the carbon footprint of cartridges and their disposal by up to 84%.[19]

COMMUNITY AND SOCIAL PROSPERITY

Lowering access barriers

By making everyday products more affordable through resale, renting, and donation models, more people will have the opportunity to increase their quality of life, and more business opportunities will arise, without increasing demand for virgin materials.[20]

Business cost savings while benefiting local communities

By using Globechain's platform to pass on unwanted office furniture to the charity Growing Networks, the company Telefonica saved around GBP 3,000 in landfill charges and skip hire costs. The charity also saved between GBP 3,000 and GBP 4,000 on the cost of new furniture.[21]

RESOURCE USE

Reducing need for new products by renting clothing

Per renter per year, online rental of clothes can result in 14 fewer garments being produced and disposed of, equivalent to net water savings of 37 m^3 and net material savings of USD 38 per person.[22]

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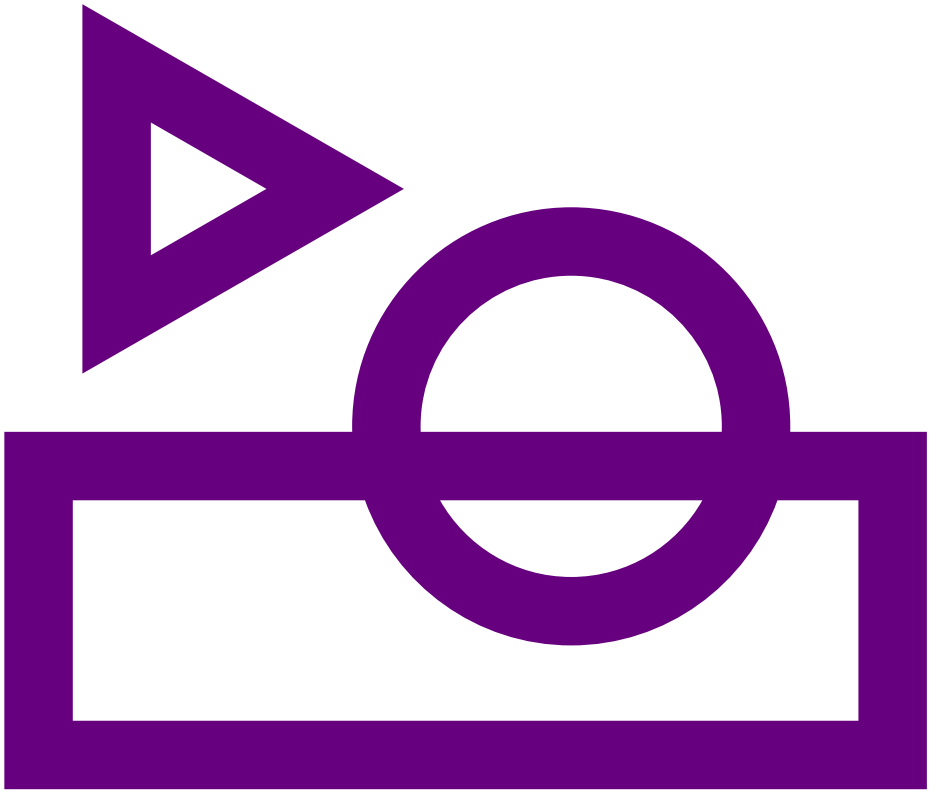

OPERATING AND MAINTAINING PRODUCTS IN A WAY THAT PROLONGS USE

ELLEN MACARTHUR FOUNDATION

Discarded consumer products represent a substantial economic and resource loss and contribute to unsustainable resource consumption and waste generation. Solutions to maximise product use in cities can counter these negative impacts. Prolonging the use of products and their component parts is key and can be achieved by models that enable maintenance, repair, refurbishment, and cascaded use where products and parts are resold at reduced prices.

CASE FOR CHANGE

23% of electronic and electrical equipment (EEE) items taken to recycling collection sites in the UK could be resold immediately or viably repaired and then resold[1]

Over their lifecycle EEE items purchased in the UK emit **196 million tonnes** of CO_2[2]

15 Mt of furniture are discarded annually in the US. Only **2%** is recovered while the actual potential in the used furniture market has been estimated as **USD 10 billion** per year.[3]

Raw materials account for around **40%** of the cost base of European manufacturing firms. This could be significantly reduced by switching to models that enable the reuse of products, the remanufacture of components, and the recycling of materials[4]

50%

Up to **50%** of people would, under the right conditions, be willing to have used or refurbished products[5]

EXAMPLES OF CIRCULAR ECONOMY OPPORTUNITIES

Empowering repair to extend product cycles

Even though the commercial repair market is well established, products are increasingly discarded when they break because repair seems practically impossible or financially unattractive.[6] However, promoting individual, community, and commercial repair activities can increase product life and resource efficiency while strengthening the local economy. The introduction of digital manufacturing, such as 3D printing, also makes repair more feasible as individuals and businesses can make spare parts locally.[7]

Refurbishing products for reuse

Many products are discarded despite still being functional – perhaps a sofa looks worn or a phone is replaced because a newer model is released. Many of these discarded products are stored for years, losing further value, before finally being disposed of.[8] Recovering these items to upgrade or refurbish[9] to a condition that makes them suitable for resale and reuse is economically feasible and entails little resource consumption for many product groups. While refurbishing might include repair, it can also cover simpler actions such as cleaning or repainting. Certified refurbishing schemes that can guarantee 'as new' product standards with a warranty are increasing in popularity, as they can reduce production costs and purchase prices. Artificial intelligence can help automate and optimise the sorting, classifying, and pricing of recovered items.[10]

EXAMPLES OF WHAT URBAN POLICYMAKERS CAN DO

Through **public procurement**, city governments can support the market for repaired and refurbished products. This could be combined with product-as-a-service schemes where city governments procure access to products in a service contract that includes repair, upgrade, and take-back. **Capacity building** through education and skills development in repair and refurbishment, along with the provision of open repair guides and workshop space, is also key to ensure the local labour market can meet the demand. **Regulations** and **fiscal measures** can incentivise longer use phases, such as via Extended Producer Responsibility (EPR) schemes or tax breaks on repaired or refurbished products.

To explore further see **Policy Levers**

EXAMPLES OF LINKS TO OTHER SYSTEMS AND PHASES

Products: Accessing Product-as-a-service business models will benefit from and incentivise product longevity and thereby increase demand for repair and refurbishment expertise and services.

Products: Designing Design for disassembly to ease repair and refurbishment will be crucial to the business case of these activities.

RELEVANT CASE EXAMPLES

Global platforms for repairers

iFixit is an open-source website and global community of repair technicians and fixers that teaches people and businesses how to fix almost anything. To do this, iFixit is building partnerships with manufacturers to help them create repair organisations, both internally and with their customers.[11]

Inclusive repair programme in Brazilian cities

Through the national Computers for Inclusion programme, cities such as Belo Horizonte and Curitiba are tackling electronic waste, digital exclusion, and youth skill gaps and unemployment simultaneously. The project aims to train young, vulnerable people to refurbish computers that will equip public libraries and schools with fully functioning IT equipment to support digital inclusion of low-income groups.[12] (see Cities case study: *Belo Horizonte*).

Repair and resale community hub in Munich

Halle 2 is a repurposed shoe shop in Munich that has been turned into a multi-purpose hub where residents can purchase second-hand items, access repair services, and take part in events and seminars where they can learn how to repair products themselves. Seven months after its launch, Halle 2 has agreements with 11 partners, allowing it to recruit and train more people. Halle 2 has sent around 3,600 electronic devices for checking, earning EUR 50,000 from the eventual sale of these devices, and has sold a total of 3,250 other items, which have generated EUR 350,000 in revenue.

Remanufacture of office furnishings in Wales

By incorporating reuse specifications in the public tender for its new office fit-out (including office equipment, furniture, and flooring), Public Health Wales (PHW) diverted 41 tonnes of waste from landfill – with a CO^2 saving of 134 tonnes. Additionally, through the careful selection of suppliers, permanent jobs for several disabled and long-term unemployed people were created.[13]

Certified refurbished and pre-owned products

Amazon Renewed is Amazon's platform for used products. The products listed as Certified Refurbished, Pre-Owned, and Open-Box have been inspected and graded to 'Like New' condition and come with a 12 month warranty. The refurbishment process typically includes a full diagnostic test, replacement of any defective parts, a thorough cleaning and inspection process, and repackaging by the seller. Besides being a new revenue channel for Amazon, the platform also helps individual refurbishers to scale their businesses and offers customers cheaper products with a guarantee of quality.[14]

'Pre-consumer waste' – a BRL 7.7 billion opportunity

In Brazil, around 5% of electronic products worth BRL 7.7 billion are returned to their manufacturers due to a flaw or imperfection after which they cannot be sold as new products, because of local regulations. eStoks is a company tapping into this opportunity. They collect the returned products and make use of them. In volume terms, 50–55% of products are refurbished and re-sold and 20–25% are repaired and re-sold. The remaining 10–15% – the most damaged – are dismantled, their components are used to repair other products. eStoks has its own retail stores that offer electronic products at affordable prices, thus opening up technology and high-quality home appliances to lower-income consumers.[15]

EXAMPLE OF BENEFITS

ECONOMIC PRODUCTIVITY

Capturing additional business opportunities

By only selling products once, brands and retailers are missing out on the opportunity to serve other customer segments. WRAP estimates that the value of 1–3 year-old electrical and electronic products (which cost GBP 2,400 to purchase) in a typical household is roughly GBP 400.[16] Based on this, WRAP estimates the UK market for pre-owned products of these types could be up to GBP 3 billion.[17]

Increasing economic activity

Every 1% increase in activities related to longer product lifetimes (maintenance, repair, rental services, etc.) in Europe has a total net value added of EUR 6.3 billion.[18]

JOBS, SKILLS, AND INNOVATION

Creating jobs in electronics refurbishment

Refurbishing 1,000 tonnes of electronics creates 13 times more jobs than recycling the same amount.[19]

Creating jobs through reuse

In Scotland, up to 150,000 tonnes of reusable materials are currently either being disposed of or being sent to lower-value recycling. Capturing just a quarter of these additional materials could benefit the Scottish economy by GBP 104 million per year and generate an extra 3,000 full-time jobs.[20]

COMMUNITY AND SOCIAL PROSPERITY

Increasing access and inclusion

Pre-used items, such as IT equipment, have a lower cost which makes them more accessible to customers, which is especially beneficial to lower-income groups.[21]

HEALTH AND ENVIRONMENT

Reducing CO^2 emissions through product reuse

WRAP estimates that modest changes in the UK EEE manufacturing and retail sector, which increase reuse by 10%, could reduce CO^2 emissions by 220,000 tonnes.[22]

Reducing CO^2 emissions from EEE and furniture remanufacturing

In Europe remanufacturing of consumer electronics, white goods, and furniture reduced CO^2 emissions by 308,000 tonnes in 2015.[23]

RESOURCE USE

Reducing resource demand in the EEE sector

WRAP estimates that modest changes in the UK EEE manufacturing and retail sector, designed to increase product reuse by 10%, could reduce resource demand by 30,000 tonnes per year.[24]

Saving materials by remanufacturing

In Europe remanufacturing and refurbishment of consumer electronics, white goods, and furniture reduced demand for materials by 226,000 tonnes in 2015.[25]

Saving resources in printer production

A study comparing a standard printer with a modular one found that for the standard model remanufacturing achieved a 25% saving of materials and energy compared to manufacturing a new product, while the equivalent savings for a modular printer, designed for disassembly and remanufacturing, were 50% for materials and 65% for energy.[26]

ENDNOTES

1 WRAP, *Switched on to value: powering business* (2017) p. 17

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4 WRAP, *Electricals industry could realise £billions in financial benefit*, wrap.org.uk (18 July 2017)

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7 Circulate, *Brands team up to see how 3D printing can revolutionise repair* (8 November 2018)

8 For example, in Australia there are almost as many mobile phones in storage (23 million) as there are people (25 million) E. Dominish *et al.*, *"Slowing" and "narrowing" the flow of metals for consumer goods: evaluating opportunities and barriers*, Sustainability (2017) p. 7

9 Refurbishing products is here used synonymously with remanufacture and reconditioning as these terms are used interchangeably depending on the product group. Upgrading refers to adding a new component that improves performance or aesthetics, for example adding a new camera in pre-used smartphone

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23 European Commision, *Remanufacturing market study* (2015) p. 45

24 WRAP, *Switched on to value* (2013) p. 8

25 European Commision, *Remanufacturing market study* (2015) p. 45

26 E. Dominish *et al.*, *"Slowing" and "narrowing" the flow of metals for consumer goods: evaluating opportunities and barriers*, Sustainability (2017) p. 7