EXPLORING THE GLOBAL

ENVIRONMENTAL AND SOCIO-ECONOMIC EFFECTS

OF PURSUING A

CIRCULAR ECONOMY

April 2020

Case studies on

DENIM JEANS & MOBILE PHONES

CIRCLE ECONOMY

WHO WE ARE

We work to accelerate the transition to a circular economy. As an impact organisation, we identify opportunities to turn circular economy principles into practical reality.

With nature as our mentor, we combine practical insights with scalable responses to humanity's greatest challenges.

Our vision is economic, social and environmental prosperity, without compromising the future of our planet.

Our mission is to connect and empower a global community in business, cities and governments to create the conditions for systemic transformation.

EXECUTIVE SUMMARY

GLOBAL EFFECTS IN PURSUIT OF A CIRCULAR ECONOMY

The interdependence of value chains in a highly globalized economy and the continuing vulnerability of low-income countries are evident in current research and debates. Therefore, moving towards a future that is circular, inclusive and sustainable on a global scale also requires taking into account the potential environmental and socio-economic impacts of circular economy strategies beyond national borders. This scoping study explores how Dutch and EU circular economy policies and initiatives may impact low-income countries.

THE IMPORTANCE OF CONTEXT

The value chain context, the circular economy strategy being pursued, as well as a product's economic contribution and environmental footprint have an influence on the potential positive and negative effects that could result. Therefore, this study provides a deep dive into denim jeans and mobile phones, two exemplary products with globalised value chains (both upstream and downstream) and significant potential for circular economy initiatives. From resource extraction to end-of-life, the study visualises and highlights the most important countries involved in these value chains. Moreover, it describes the impacts of Dutch and EU circular economy policies on developing countries by looking at indicators such as land use, pollution of water and soil, work and income, CO_2 emissions and health and safety.

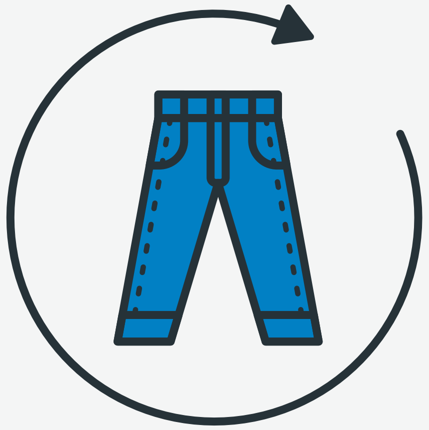
CIRCULAR DENIM JEANS

The iconic pair of denim jeans, of which the average Dutch person has between 5-6 in their wardrobe, has a value chain that spreads around the globe and entails an energy and chemical-intensive manufacturing process. The main environmental impacts across the value chain relate to water and air pollution, due to chemicals and agents used for dyeing and finishing techniques. Moreover, cotton requires large quantities of water, fertilisers and pesticides. Negative social effects are identified in the lack of decent work opportunities, forms of forced labour and worker health and safety. At end-of-life, an estimated 70% of clothing is currently disposed of via regular household waste. It is also associated with negative environmental effects caused by dumping of low-quality textiles on landfills and in the environment.

The industry surrounding denim jeans is taking steps to become more sustainable and shows increasing activity from both public and private actors aiming to increase the circularity of the product. Denim jeans are characteristized by qualities such as durability and mono-materiality, making it a strong showcase for lifetime extension and reuse, as well as a test case for remanufacturing and recycling technologies. Circular economy policies and initiatives are mostly targeting refuse, reuse, recycle and recover strategies. The potential environmental effects are mainly positive, driven by smarter use of resources both upstream and downstream. This includes decreases in water use and soil pollution, as a result of reduced cotton production and fabric dying.

An example is MUD Jeans, which produces a pair of jeans consuming 581L of freshwater, compared to the industry average of 7,000L. However, from a socio-economic perspective the effects are more uncertain and examples indicate both positive and negative impacts.

If demand for virgin cotton decreases or less denim waste is exported, positive effects include improved health and safety due to a decrease in pollutive practices. Negative effects relate to a decrease in low-entry and informal jobs, depriving vulnerable communities of a way out of poverty. At the same time, there is the potential for low-income countries to generate alternative income, for example if recycling facilities are constructed in regions close to extraction and production locations.



CIRCULAR MOBILE PHONES

A new mobile phone in the Netherlands is generally replaced after an average use period of 2.5 years. All materials and components are manufactured in a highly complex and globalised value chain, that is notoriously opaque. Large amounts of virgin resources and energy are needed to produce a mobile phone, with accompanying negative environmental and social implications that mainly revolve around the non-abundant precious metals and related highly pollutive mining practices. This usually goes hand-in-hand with lower wages and exploitation of workers. When replaced, approximately half of all mobile phones are estimated to end up as hibernating stock in Dutch households. After disposal it becomes part of e-waste, dubbed the fastest growing waste stream worldwide. Outside the EU, there are challenges in the proper recycling of mobile phones and the issues of illegal dumping of waste. The ecotoxicity caused by informal e-waste recycling can contaminate the food chain and drinking water, causing health issues in local communities.

Nevertheless, awareness of the negative impact throughout the value chain seems to be increasing. Both public policies and private initiatives for a more responsible and sustainable production and consumption system of “circular” mobile phones are slowly gaining ground. Examples include The Ecodesign Directive that pushes for replaceable batteries and universal chargers and the e-waste offsetting service offered by Closing the Loop, through collecting end-of-life mobile phones in African countries for proper recycling. The majority of circular economy policies and initiatives target slowing down replacement rates (e.g. through repair) and increasing rates of collection and recycling. On the environmental side, a decrease in pollutive and related effects would be expected.

However, there is a risk of increased landfilling rates if high quality second-hand EU mobile phones are replaced by lower quality products, with a shorter timespan, in low-income countries. On the socio-economic side, similar to denim jeans, the effects could swing in both directions. More circular practices are expected to have positive health effects due to decreased pollution and precarious work, associated with mining and manufacturing. On the other hand, it could also involve a reduction in (informal) jobs, thereby eliminating prospects for income for vulnerable communities.

MIXED EFFECTS FROM AN ENVIRONMENTAL AND SOCIO-ECONOMIC PERSPECTIVE

What surfaces from both deep dives, is that the expected effects are largely positive from an environmental and health perspective. This results from the targeted reduction in demand for virgin materials if recycled content increases, or an overall reduction in product demand if the use phases are extended. The same holds true for the end of the value chain: extended lifecycles would diminish export of used products that would otherwise end up in improper waste treatment. All other things remaining equal, existing negative effects, such as water stress, pollution of water and soil, health issues related to pollution and CO_2 emissions, diminish. From the employment and income perspective, effects are to be monitored closely, since these can be expected to be negative, especially for low-entry, low-income jobs. This would be the consequence of a reduction in jobs associated with changes in upstream and downstream activities. However, depending on e.g. the location of recycling or reprocessing facilities, it could mean a shift in type of jobs required, which implies the need for reskilling of workers.

CONTEXTUALISED CIRCULAR ECONOMY POLICIES AND INITIATIVES

Each value chain has its specific challenges; from pollutive resource extraction and manufacturing processes, to low standards of occupational health and safety and low-income jobs. From a policy perspective, it is recommended to carefully assess interactions of circular economy policies and initiatives with broader macro-economic trends such as population growth and a rise in middle-income households. In general a global perspective is advisable, since these trends may influence demand for products in emerging economies, and thereby increase demand for raw materials. Here it is important to target activities at the start of the lifecycle, such as responsible mining practices, that benefit both the environment and local communities in low-income countries. Secondly, it is recommended to carefully design an approach that considers extending the useful life of products in low-income countries. In the case of mobile phones, due to the high potential for lifetime extension in low-income countries with a strong demand for this product, the focus should not only be on extending the lifetime in the Netherlands or the EU. This might cause a rebound effect in the form of a growing influx of lower quality mobile phones to replace second-hand mobile phones that comply with high quality standards required for the Dutch market. Finally, when it comes to recycling, it could be most impactful to locate proper recycling facilities in low-income countries where waste is posing a significant threat to the environment, e.g. through ecotoxicity, and related negative health impacts.

GLOBAL TO LOCAL COLLABORATION FOR A SUSTAINABLE FUTURE FOR ALL

This scoping study sets out to specify the link between national circular economy policies and international implications and identifies areas for further research and collaboration. Bringing together wider viewpoints of actors involved across both value chains researched can contribute to a more detailed view of the complex nature of these systems, enhancing both transparency and triggering much needed collaboration to increase the potential positive effects and mitigate the unintended negative effects of a transition to a circular economy. A sustainable future can become reality if we apply the concept of the circular economy to collectively reimagine and redesign our systems, to ensure a safe and just space for us all, which respects and treasures the natural environment.

TABLE OF CONTENTS

1 CONTEXT & INTRODUCTION

LOOKING BEYOND BORDERS

Moving towards a future that is circular, inclusive and sustainable on a global scale requires that we take into account the potential impacts of circular economy strategies beyond national borders. While realising circular economy action plans in the European Union and in The Netherlands, the current interdependencies with other countries, including those that are low-income, have to be taken into account. The effects and impacts, both environmental and socio-economic, will differ widely from product to product depending on the respective value chain context, the circular economy strategy being pursued, as well as the product's economic contribution and environmental footprint.

THE IMPORTANCE OF CONTEXT

Earlier analysis by PBL Netherlands Environmental Assessment Agency concluded that the impact of circular economy initiatives in global value chains are highly context-specific. Therefore, this scoping study focuses on two exemplary, yet different products (in relation to production process and usage) to put the analysis in perspective; denim jeans and mobile phones. The rationale for selecting these two products is twofold; the globalised nature of both value chains (both upstream and downstream) and the significant potential of circular economy initiatives for these specific product groups.

This scoping study explores how Dutch and EU circular economy policies and initiatives may impact low-income countries. The objectives of this scoping study are to:

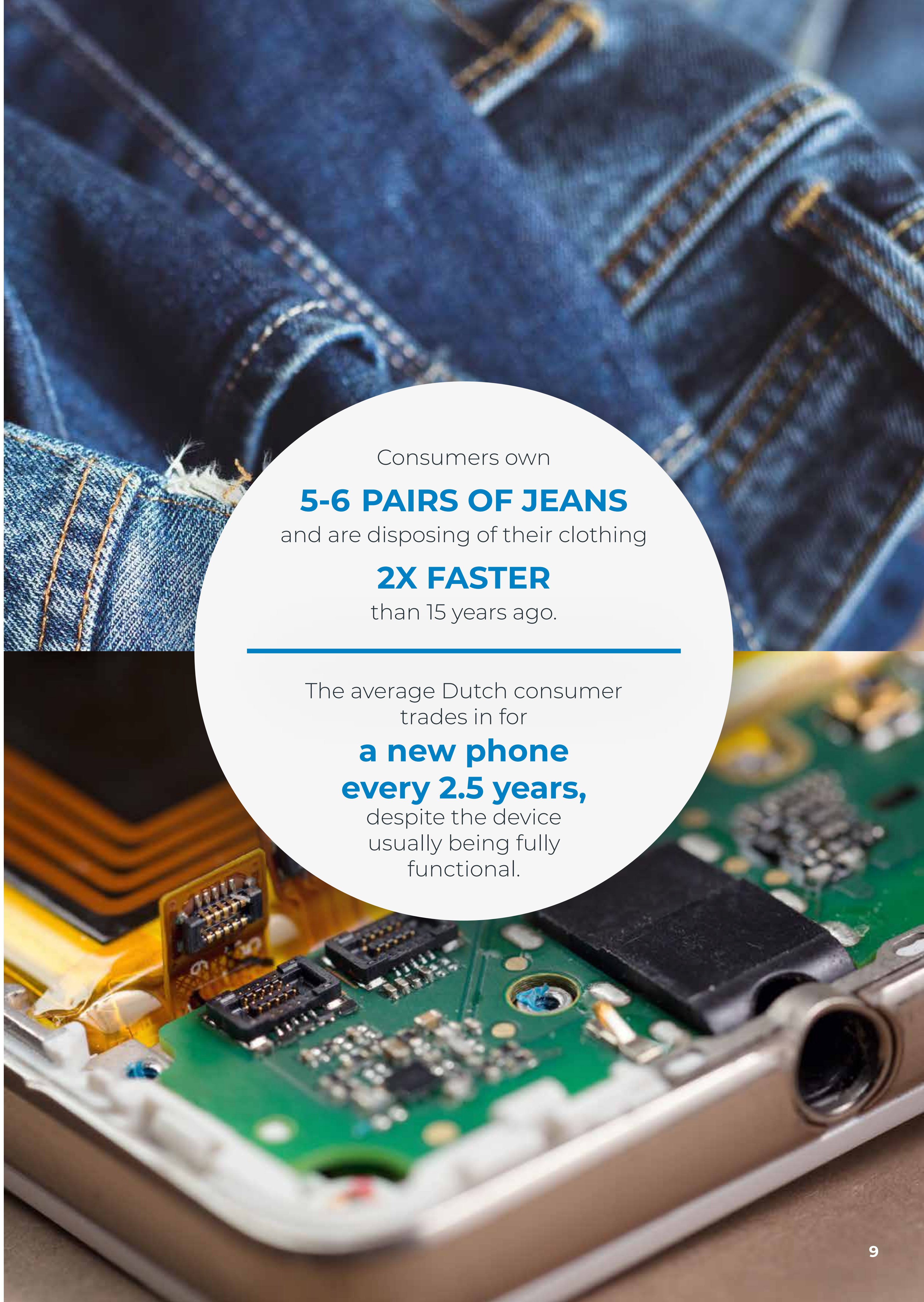
- Map global material and product flows for denim jeans and mobile phones.
- Explore current and potential up- and downstream environmental and socio-economic effects.
- Gain an understanding of the potential impact areas of circular economy initiatives and/or policies active, or foreseen to be implemented in the Netherlands or the EU.
- Uncover gaps in knowledge, data and research.

THEORY AND PRACTICE COMBINED

This report is a synthesis of the available knowledge on the potential environmental and socio-economic effects that pursuing circular economy strategies (i.e. a public policy or a private initiative) in the Netherlands or the European Union (EU) may have in low-income countries involved in the two value chains.
It combines desk research and outcomes of interviews with experts working in or researching the value chains in focus.

We researched academic literature, general media, not-for-profit, governmental and industry reports. We also looked at Dutch and or EU policies and initiatives that focus on mobile phones and denim jeans directly, and the electronics and textiles industries more broadly to provide context and to make informed assumptions where specific product related data was unavailable. The expert interviews provided practical examples to illustrate the desk research and a critical view of and reflections on the analysis.

A detailed description of the research approach is included in chapter 2. The analyses are reported in two different chapters, starting with a deep dive into denim jeans, followed by the mobile phone value chain.



2 RESEARCH APPROACH

To understand the potential impact areas of Dutch and EU circular economy strategies across global value chains, we applied the following five steps in our analysis. The intention in this exploratory study is to illustrate the interconnectedness of systems and actors, as well as the diversity and complexity of cause and effect in pursuing a circular economy.

1. UNDERSTANDING A LARGER ECOSYSTEM VIA ONE REPRESENTATIVE PRODUCT

For both value chains we begin with framing the study by placing each product in the perspective of its industry. Denim jeans are a symbolic part of the textiles industry, as much as mobile phones are symbolic for the electronics industry. The larger pool of products in the respective industries largely have a similar value chain, share upstream sources, manufacturing processes, downstream destinations, and in some cases even material composition. Similarly, we need to consider the Dutch and EU consumption rates of these products in comparison to global consumption. This provides nuance to the potential order of magnitude and the potential effects Dutch and EU policies and initiatives could have.

2. MAPPING THE PRODUCTION AND CONSUMPTION SYSTEM

Material Flow Analysis (MFA) was employed to map the mass-based material, product and waste flows in the production and consumption system of denim jeans and mobile phones. The resulting system map is a visual aid to understand dynamics across the value chain of each product. First, by breaking down the composition of a generic representation of the product and outlining the consecutive value chain steps from resource extraction to final assembly. Second, by assigning the probability of the product to enter the different life cycle scenarios and eventual end-of-life destinations. The geographical dimension is added by highlighting the key countries involved per value chain step.

3. IDENTIFYING SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT AREAS

To enrich the MFA, this step highlights the most prevalent socio-economic and environmental impacts per lifecycle phase (from resource extraction to end-of-life). Through literature research and expert interviews, we have identified how the material and product flows are associated with positive or negative environmental and socio-economic effects (see table 1. for examples of the main impact areas).

SOCIO-ECONOMIC	ENVIRONMENTAL	
• Work & Income	• Material use (e.g. plastics, metals)	• Pollution (of water, air, land)
• Health & Safety	• Land use (incl. deforestation)	• Water
• Peace & Stability	• Climate change (incl. CO_2 emissions)	• Biodiversity
• Gender equality		

Table 1. Examples of environmental and socio-economic impact areas

The environmental and socio-economic effects are often interdependent. For example, land and water pollution also negatively affects human health as well as yields in agriculture, thereby negatively impacting income for farmers. Yet, socio-economic and environmental effects are highlighted separately.

4. IDENTIFYING RELEVANT CIRCULAR ECONOMY POLICIES AND INITIATIVES

As a next step, we have compiled a concise and non-exhaustive overview of public and private circular economy initiatives and policies that target the products (or the wider industries) under study. These are classified according to the 9R-strategy framework that is created by PBL by combining existing R-lists to be more comprehensive.[2] The R-strategies (see table 2.), summarise various interventions that can be applied to reduce material consumption, avoid waste generation and increase material cycling.

5. EXPLORING POTENTIAL EFFECTS ACROSS NATIONAL BORDERS

As the final step, we explore how the Dutch and EU circular economy policies and initiatives (compiled in step 4) could affect the main environmental and socio-economic impact areas (identified in step 3). Where data is available, we have given an indication of the order of magnitude in, for example, number of jobs or size of exports. In the exploration of effects, we differentiate between upstream and downstream effects in the value chain, reasoned from the first use phase in the European context. This distinction is made as specific policies may impact countries involved in the resource extraction and production phases (i.e. upstream), whereas other policies target countries involved in the second-hand, or end-of-life phase (i.e. downstream). The effects in essence are hypotheses of potential scenarios, since various types of knowledge gaps surfaced. For the validation of the potential effects, we have consulted the experts or extrapolated their insights.

		STRATEGY	DESCRIPTION
Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	Rethink	Make product use more intensive (e.g. through sharing products, or by putting multi-functional products on the market)
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	R3	Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date
	R6	Remanufacture	Use parts of discarded product in a new product with the same function
	R7	Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	R8	Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	Recover	Incineration of material with energy recovery

Table 2. R-Strategies

3

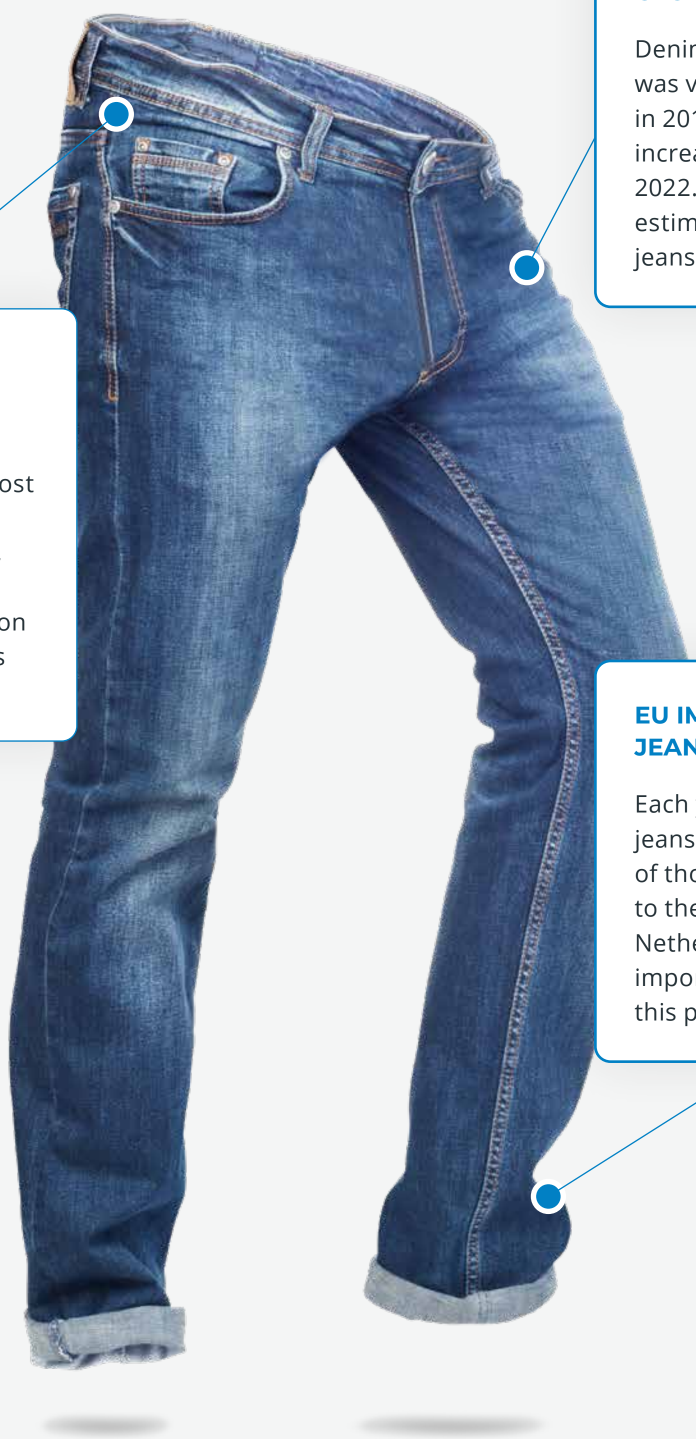
IN FOCUS: DENIM JEANS

INTRODUCTION TO DENIM JEANS: AN ICONIC ITEM OF CLOTHING

Denim jeans represent an iconic piece of clothing, both due to its cultural meaning as well as its physical characteristics. Denim jeans have evolved from resistant workwear trousers in the late 1800s to a contemporary staple in many consumer wardrobes today.[3,4] According to a Cotton Incorporated Global Lifestyle Monitor survey in 2018, the average consumer owns 5.4 pairs of jeans.[5] The core strength of denim is perceived to be its quality and durability. Chiefly composed of cotton fibre, a commodity that can be sourced across more than 75 countries.[6]

Historically the denim jeans value chain has been associated with significant negative environmental impacts related to water and energy consumption and use of chemicals. These impacts originate at various stages of the production process, including cotton growing, dyeing, fabric finishing and garment finishing.[7,8] However, being an essential garment present in consumer wardrobes and having a relatively homogeneous and simple material composition, denim jeans today represent the ideal candidate in textiles to drive sustainable improvement.

Over the past decade the denim industry has made notable technological and innovative advancements towards reducing its environmental impact in comparison with other textile products,[9,10,11] including initiatives elaborated on in this study by organisations such as MUD Jeans on page 21, which aim to increase the circularity of the product. The main drivers for these improvements are linked to a high potential for lifetime extension and reuse, due to its durability and lack of dependence on seasonal trends. Other relevant factors are a denim product's usual mono-materiality and material and component consistency, which provide homogeneous feedstock for remanufacturing and recycling. Hence, taking a closer look at the potential effects across the value chain of scaling circularity practices and implementing circular policies within the EU and the Netherlands remains of utter importance.



US$ 56.55 BN[14] VALUE OF GLOBAL JEANS MARKET

Denim jeans global market was valued at US$ 56.55 bn in 2017 and is expected to increase to US$ 59.46 bn by 2022. Europe represents an estimated 34% of the global jeans market in value.

24.4%[12] COTTON GLOBAL MARKET SHARE

Cotton is the second most used fibre in textiles, after polyester. In 2017, it represented almost a quarter of the 103 million tonnes of fibre that was produced globally.[13]

EU IMPORTS 27%[15] OF JEANS PRODUCED

Each year around 2 billion jeans are produced.[16] 27% of those jeans are imported to the EU. Of this, the Netherlands is the fifth importer within the EU of this product.[17]

THE CURRENT STATE OF THE DENIM JEANS VALUE CHAIN

A GLOBALISED, COTTON-BASED VALUE CHAIN

The value chain for denim jeans spreads around the globe. The predominant material used in this value chain is cotton. This is a commodity crop grown in over 75 countries, employing around 26 million cotton farmers worldwide6 and employing an estimated 300 million people across the sector when including transport, ginning, baling and storage.[18] The main countries that grow and commercialise this crop are China (26%), India (25%), United States of America (16%) and Brazil (10%).[19] While West African countries together only account for approximately 8% of global cotton growing,[20] their economies are highly dependent on this crop. For example, cotton represents around 60% and 25% of Burkina Faso's and Benin's exports (in monetary value).[18]

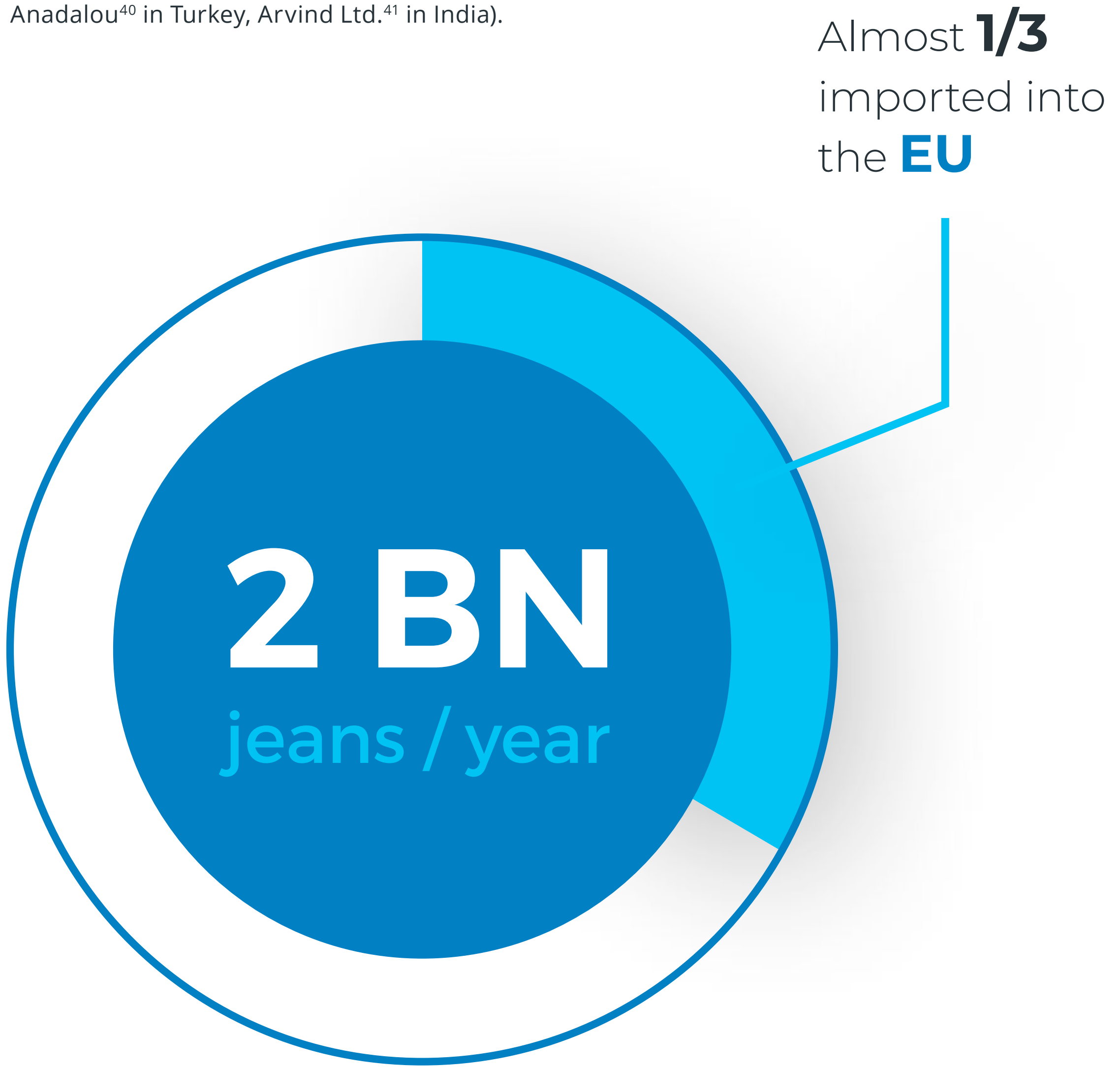
Although this crop represents a relevant source of economic development for several low and middle-income countries, the way in which the material is grown and harvested should be closely monitored, as cotton requires large quantities of water, fertilisers and pesticides, and occupies significant portions of land. 2.5-3% of global agricultural land is used for cotton growing[21] and 4% of arable land has already been left fallow due to intense cotton cultivation.[8] Especially in water stressed areas, the potential effects of unsustainable cotton growing may result in severe outcomes, as has been observed in the past with the shrinking surface of the Aral Sea.[22] An example on water usage for a pair of jeans is found on page 25.

AN ENERGY AND CHEMICAL-INTENSIVE MANUFACTURING PROCESS

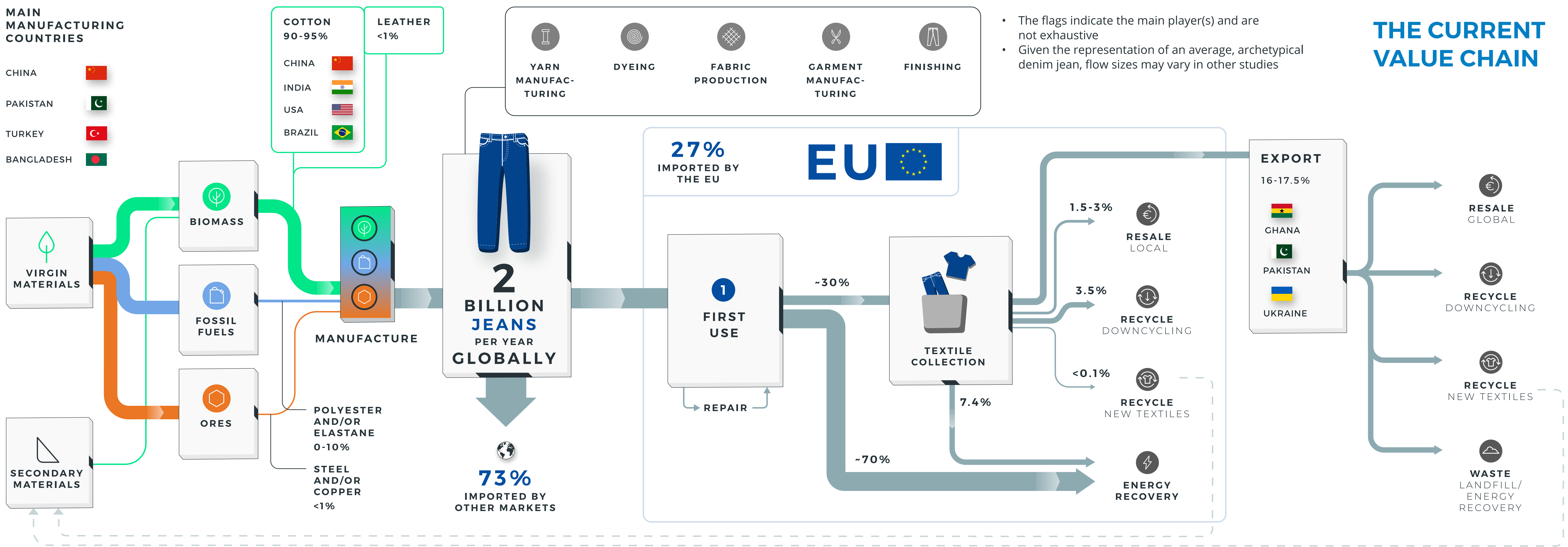
To produce jeans, stakeholders in the value chain are tasked with processing the cotton fibre, spinning and dyeing the yarns, weaving the denim fabric, cutting and sewing the garments and finally introducing any finishing to the product. Most of the fabric is produced in China, Pakistan and Turkey, while most of the jeans imported into the EU are cut and sewn in Bangladesh, Turkey and Pakistan.[23] The main environmental impacts across the value chain relate to water and air pollution, due to chemicals and agents used for dyeing and finishing techniques.[24,25,26] With the combined textile, clothing and footwear manufacturing value chain accounting for a global workforce of 60-75 million people,[27] negative social effects are identified in the lack of decent work opportunities, forms of bonded/forced labour and worker health and safety. According to a recent report by the Impact Institute commissioned by ABN AMRO, the 'true' purchasing price per pair of denim jeans for retailers should be 30 euros higher. This puts a price on direct external costs related to the production of a pair of jeans, such as the current negative environmental effects of cotton production and the lack of fair wages in production.[23]

A RESOURCE WITH MULTIPLE HIGH VALUE RETENTION STRATEGIES

From the two billion jeans currently produced yearly,[16] almost one third are imported into the EU and purchased by consumers across EU countries. For example, in the Netherlands, it is estimated that each person buys on average 1.2 jeans per year and has between 5-6 jeans in their wardrobe.[17] At end-of-life most clothing is currently being disposed of via regular household waste (~70%).[28] In some regions of the EU a separate collection for textiles is already in place. Of the textiles that are collected (~30%), 5-10% are resold locally in the EU, and 54-59% are exported for reuse, mostly to Eastern European or African countries, which have developed a second-hand economy based on these textiles.[29] Main importers of EU used textiles outside the European Union are Ghana, Pakistan and Ukraine.[30] The estimations on the current disposal of textiles are for the whole industry, as through this research, specific data for the denim waste stream is not widely known. Nevertheless, when observing trends in second-life or end-of-use destinations for denim specifically and in discussion with experts, denim jeans seem to have higher value for collectors and sorters in comparison with other textile waste, and are increasingly separated to be sold as feedstock for material reuse or recycling. Recent initiatives can also be seen in denim brands increasingly taking control of their product after the point of sale and initiating various strategies to extend the product's first life (care[31], repair[32]) or in facilitating a second life (rental[33], recommerce[34]) within the EU. Simultaneously, other businesses are starting to recycle denim waste, both from industrial and consumer sources, though still at very limited quantities. The recycling may happen either locally within the EU (e.g., Recovertex - Spain,[35] Re:newcell - Sweden,[36] Infinited Fiber - Finland,[37] SaxCell - Netherlands[38]) or abroad, closer to denim production hubs (e.g. Bosa,[39] Orta Anadalou[40] in Turkey, Arvind Ltd.[41] in India).



THE CURRENT VALUE CHAIN



	RESOURCE EXRACTION	MATERIAL PROCESSING & PRODUCTION	GARMENT MANUFACTURING	ACTIVE LIFETIME [EU]	COLLECTION	END-OF-LIFE
ENVIRONMENTAL	23 million tonnes of cotton fibre produced/year, the 2nd most used fibre for textiles with a market share of 24.4%. 68% of the freshwater consumption of jeans lifecycle (total av. 5700-15000 lts) happens at cotton growing stage while many times coinciding with high and extreme water stress areas.	CO_2 equivalent to produce one pair of jeans ranges between 7.18 CO_2 eq - 33.4 CO_2 eq. Most of these are accounted for within fabric manufacturing (excluding consumer use).	0.5 kg of chemicals used to produce one pair of jeans, including those used in cotton processing, denim finishing such as bleaching, whiskering, stonewashing, sandblasting, PPP, and dyeing.	1.3 tonnes of primary raw materials per person for the production and handling of clothing, footwear and household textiles sold in the EU. 85% of them are from other regions. 104m³ of water per person for the production and handling of clothing, footwear and household textiles sold in the EU. 92% of the water used was from other regions.	Around 70% of all textile waste generated ends up mixed in general household waste. An estimated 640 million pairs of jeans thrown out every year in the EU.	Around 100 containers arrive to Ghana every week with used textiles. Some are clothes for the second hand market, but many of our used textile that are considered waste end up in their landfills.
SOCIO-ECONOMIC	26 million cotton growers spread in 75 countries. In several countries cotton earnings account for 40-60% of GDP (e.g. West African Burkina Faso, Benin, Mali). 16% of insecticides and 7% pesticides are used for cotton growing globally. Combined with lack of adequate equipment may lead to health issues.	350 million people (est.) involved in cotton sector when considering family labour, hired farm labour and workers in transportation, ginning, baling and storage. A shift to trading cotton yarn and fabrics rather than raw cotton has emerged recently, to obtain value-added from mills. This affects economies highly dependant on cotton growing but with no processing industry.	60-70 million people (est.) are employed across the clothing production value chain. Direct dumping of chemicals used in dyeing and finishing into local wastewaters have lead to presence of mercury, lead, copper in drinking water, leading as well to skin diseases and other.	The largest denim importer in the EU is Germany, followed by Spain, the United Kingdom, the Netherlands, France and Italy. On average in the Netherlands each person owns 5.4 pairs of jeans.	It is estimated that 20 jobs can be created for every 1.000 tonnes of used textiles collected and sorted for reuse and recycling in social enterprises across Europe.	The EU has exported more than 2 billion US dollars in value of used textiles in 2019.

POLICIES & INITIATIVES
DENIM JEANS

DUTCH AND EU POLICIES AND INITIATIVES IN SUPPORT OF CIRCULAR DENIM JEANS

This section provides a (non-exhaustive) inventory of the circular economy initiatives and policies identified in The Netherlands and the EU, that are intended to enable or drive the transition to a circular economy.

EU POLICIES TO SUPPORT THE TRANSITION TO CIRCULAR DENIM JEANS

Currently within the textiles sector, there are only a few policy instruments implemented to secure a circular economy transition in the EU. For example, the *REACH Regulation* ensures compliance with safe use of chemicals, which contributes to circularity by **refusing** (R0) use of harmful and hazardous chemicals and enabling safe materials to be recirculated.[42] According to the latest update of Annex XVII, stricter regulations will come into place on November 1st 2020. However, to ensure the safety of these products some substances currently regulated still need to be phased out in the industry. Clothing produced up until 2007 that is still in circulation within the use and end-of-use stages may still contain some of the harmful and hazardous chemicals.[43]

Further, the separate collection of textiles at their end-of-use will be required across the EU by 2025 according to the amendment made to the EU Waste Framework Directive (2008/98/EC),[44] in connection with a **recovery** strategy (R9). This entails larger volumes of used textiles being collected on European soil, which will need to be effectively sorted and reintroduced back into the value chain as a rewearable product, or as appropriate recycling feedstock.

Building on the recently developed EU Circular Economy Package (2015) and Circular Economy Action Plan (2019),[45] as well as the Dutch Circular Economy Transition Agenda for Consumer Goods[46] (2018), several recommendations remain to be assessed by the EU and national governments. For example, by the end of 2024, the European Commission needs to consider whether targets for textile **reuse** (R3) and **recycling** (R8) should be introduced. The impact of increased collection rates and local (EU) reuse and recycling targets needs to be assessed to understand the best way to move forward with policy setting, whilst mitigating any potential negative rebound effects across the wider value chain.

STRATEGY		POLICY
R0	**Refuse**	EU - REACH 2020 Legislation (Use of hazardous chemical restrictions) NL - Additional requirements on formaldehyde in textiles
R1	**Rethink**	NL - Standardisation of circular textiles definition (NEN) NL - Circular Transition Agenda for Consumer Goods / Sector Plan for Textiles
R2	**Reduce**	*NL - Examine undesirable incentives that promote increased consumption and disposal rates (Recommended in Transition Agenda)* NL - 50% target reduction in the use of primary raw materials (minerals, fossil and metals) by 2030 (note: only applies to abiotic materials in jeans)
R3	**Reuse**	*EU - Reuse Targets for Textiles (Assessment recommended in EU Circular Economy Package)*
R4	**Repair**	*NL - Facilitate implementation of visible return facilities for repair (Recommended in Transition Agenda)*
R5	**Refurbish**	
R6	**Remanufacture**	*NL - Innovation grants to link manufacturing processes to digital or automated technologies (Recommended in Transition Agenda)* *NL - Facilitate new employment opportunities in remanufacturing; reskill workers at vocational secondary education (Recommended in Transition Agenda)*
R7	**Repurpose**	
R8	**Recycle**	EU - European Textile Regulation (1007/2011) - Labelling Requirements *NL - Green Deal on Circular Procurement (2013)* *EU - Recycling Targets for Textiles (Assessment recommended in EU Circular Economy Package)*
R9	**Recover**	EU - Separate Textile Collection by 2025 *National - EPR scheme and Innovation grants to support the establishment and affordability of the required infrastructure (only implemented in France within EU)*

Table 3. EU and Dutch policies that support the transition to the circular economy for textiles. Italic = recommended in official policy documentation; EU = implemented on an EU level; NL - Implemented in the Netherlands

Note: Other recommendations and suggestions for policies within the EU to support the transition towards a circular economy for textiles have been brought forward by organisations, advocacy and other working groups such as Ecopreneur.eu, the Fibersort Interreg NWE consortium[48] and Mistra Future Fashion.[49]

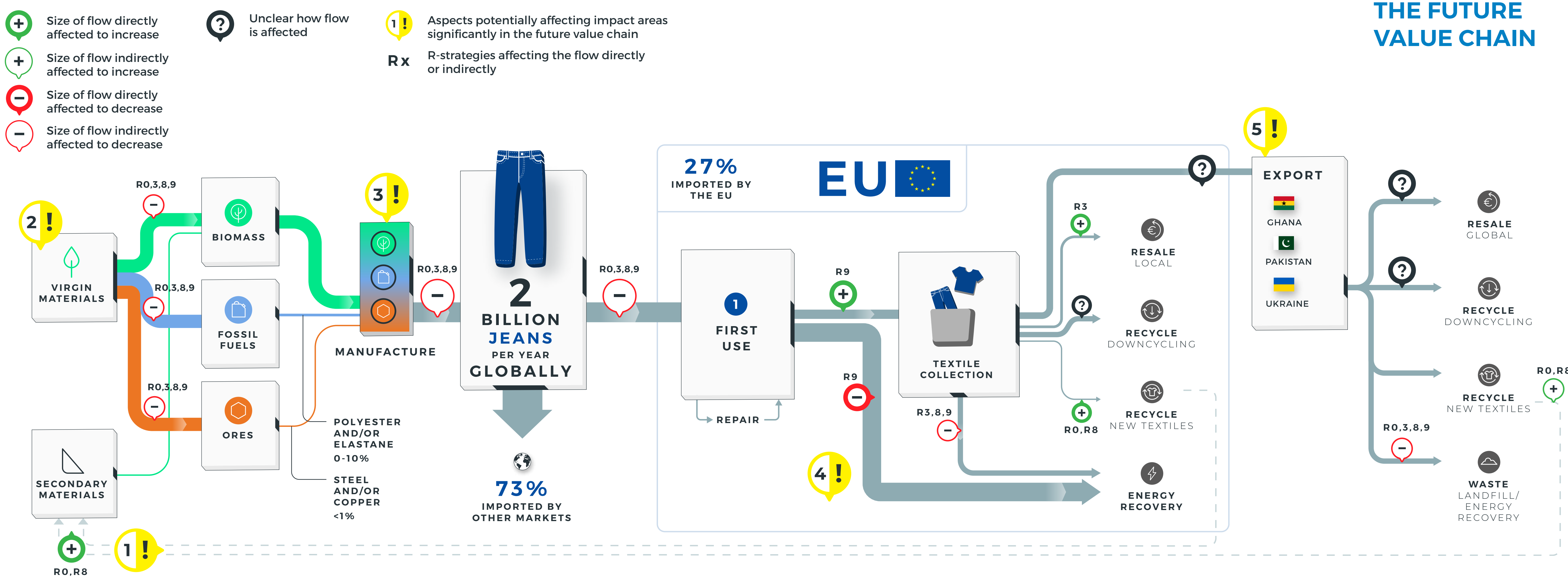
PRIVATE AND PUBLIC INITIATIVES TO SUPPORT AND SCALE THE TRANSITION TO THE CIRCULAR DENIM JEANS

In the landscape of initiatives working on circularity for denim jeans, several strategies and examples are worth mentioning. While most of these initiatives currently represent a small volume of the total denim jeans industry, their scaling potential remains to be seen. Initiatives can be found across all R-strategies, although a larger amount of initiatives have been mapped within the **rethink, reuse, recycle** and **recover** (R1, R3, R8, R9) strategies. Further, during the past years, the work within the **refuse** (R0) strategy, mainly in relation to use of chemicals and product safety, has particularly increased.[50,51] This informs the other strategies, as the potential for recycling is highly dependent on the material safety of the product. Table 4 shows a non-exhaustive list of examples of these initiatives by both private and public actors.

STRATEGY	INITIATIVE
R0 **Refuse**	World - Exhibitor restrictions for harmful use of chemicals and CSR practices at Kingpins trade show World - Chemical management guidelines (ZDHC Campaign; Kuyichi 2019)
R1 **Rethink**	World - Design for recyclability (Levi's Wellthread Line) Design for disassembly (Mud Jeans; Unspun) NL - Industry collaboration (Dutch Agreement on Sustainable Garments and Textiles; Denim Alliance; Dutch Circular Textiles Valley) World - Design guidelines (Cradle2Cradle, Jeans Redesign Guidelines Ellen MacArthur Foundation)
R2 **Reduce**	World - Consumer-facing care instruction campaign (G-STAR; Levi's) World - Water-use reduction (Waterless Tech, LCA analysis Levi's; GAP & Arvind collaboration)
R3 **Reuse**	NL - Lease a jean (MUD Jeans)
R4 **Repair**	EU/World - In-store repair service (Nudie Jeans; Levi's selected stores)
R5 **Refurbish**	EU - Second-life collection (Nudie Jeans)
R6 **Remanufacture**	EU - Remanufacturing post-industrial waste (Candiani and Atelier & Repairs) NL - Remanufacturing facilities (e.g. The Renewal Workshop in Amsterdam)
R7 **Repurpose**	World - Consumer-facing repurpose campaign (Levi's)
R8 **Recycle**	EU - Voluntary EU Green Public Procurement criteria on textile products and services - MVO 2017 NL - Collections including recycled content (10-100%) (e.g. MUD Jeans; HNST; Denim Alliance) World - Denim manufacturers with recycling facilities (Artistic Milliners; Bossa; Kilim; Arvind; ISKO; Saitex) EU - Denim recyclers (Recovertex; Filatures du Parc) NL - Denim downcycling into insulation (CIRCL) World - Partnering with research institutions to drive new technologies (GAP, H&M & HKRITA)
R9 **Recover**	NL - Collection scheme collaborations to reintroduce recycled content in garments (Kuyichi with Sympany) EU - Developing the end-of-use value chain for collectors and sorters (Fibersort Interreg NWE Project)

Table 4. Private initiatives to support the transition to the circular economy for denim jeans. EU = implemented on an EU level; NL: Implemented in the Netherlands; World = Implemented outside the EU

THE FUTURE VALUE CHAIN



EXPLORING POTENTIAL GLOBAL EFFECTS OF EU CIRCULAR DENIM STRATEGIES

Using thought experiments, we imagine a circular economy for denim jeans according to the ambitions expressed in EU and Dutch policy. Differentiating between upstream and downstream scenarios, we have hypothesized potential effects on relevant environmental and socio-economic impact areas, considering the foreseen policies in relation to the R-strategies refuse (R0), reuse (R3), recycle (R8) and recover (R9). The scenarios have been tested with the expert panel to assess the interaction with other macro trends that may have direct or indirect interactions with or consequences for the potential effects.

The visual above demonstrates the changes to the flows as well as the R-strategies that cause these changes, in a simplified manner. The aspects in the value chain that affect or are affecting the socio-economic and environmental impact areas significantly are highlighted. These effects will be discussed in detail on the next pages.

Upstream. The main targeted effects of the R-Strategies combined are an increase in demand for secondary materials, thereby a reduction for virgin cotton, as well as a reduction in demand for denim jeans in the local market, thereby reducing imports.

Downstream. On this side of the value chain, it targets reduced export of second-hand denim jeans and/or a reduced export of related textile waste. Increased recycling of denim waste may take place either locally or globally.

1 ! A novel increase in demand for secondary materials - replacing virgin cotton, may arise. Denim provides a substantially homogeneous resource to recycle.

2 ! An expected decrease in virgin raw material demand for cotton may derive in positive environmental effects related to water use and pollution. Socio-economic effects must be closely monitored.

3 ! Potential negative socio-economic effects in countries where GDP and employment are highly dependent on textile manufacturing or cotton resource extraction.

4 ! An increase in separate textile collection will prevent textiles from being disposed together with household waste, and may create an opportunity for further reuse or recycling.

5 ! A decrease in the downstream flow of denim jeans exported could reduce the current negative environmental effects caused by dumping of low-quality textiles on landfills and in the environment. Enablers for safe and successful global reuse and recycling should also be assessed.

THE UPSTREAM SCENARIO: A DECREASE IN VIRGIN RAW MATERIAL SOURCING FOR DENIM JEANS

Assuming the policies are successfully implemented within the EU, this market will be consuming a larger amount of reused garments, as well as new garments with recycled content. Simultaneously, there will be a larger volume of garments collected in a separate waste flow at their end-of-use, if the right incentives for textile collectors and sorters are put in place.

1 ! On the one hand, the availability of jeans at end-of-use that are suitable for recycling, in combination with the potential increased market uptake of denim jeans with recycled content, leads to a decrease in the need for virgin cotton fibre for this product for the European market. The share of the global jeans production imported to the EU today is 27%,[52] meaning the **decrease in virgin raw material demand** will likely follow this magnitude. Currently, the amount of recycled content that can be incorporated in one pair of jeans is usually between 15-40% of the cotton fibre needed.[53] However, this percentage may increase as emerging chemical recycling technologies for cotton develop further.[54] Additionally, the magnitude of the decrease in virgin cotton fibre will be subject to the interaction with other macro trends, including population growth and variations in natural and synthetic fibre market shares.[55,56] On the other hand, if the increase in reuse is accompanied by an extended lifetime of the product and slowed consumption patterns, there may be a **potential decrease in demand** for **newly manufactured products.**

POTENTIAL ENVIRONMENTAL EFFECTS

2 ! A decrease in demand for new cotton is likely to **decrease the water use** needed for growing cotton in the first place, which will be especially beneficial in water stressed areas[57] - unless cotton farming is replaced by another water-intensive crop. Furthermore, this may result in a related **reduction of pesticides** used in traditional cotton cultivation that are currently polluting land and water in cotton growing regions[58] - unless cotton farming is replaced by a more pesticide-intensive crop. The effects will be highly dependent on the alternative scenarios for these regions, including the potential shifts to growing alternative crops, alternative farming practices, including more regenerative and sustainable cotton growing as well as the introduction across the value chain of new materials and technologies.[59] Further, a **potential decrease** in demand for **newly manufactured products,** coupled with better dyeing and finishing practices, in line with REACH regulation, may lead to a **decrease in pollution of freshwater** due to denim jeans production.[60,61]

POTENTIAL SOCIO-ECONOMIC EFFECTS

Decreased pollution could in turn lead to positive socio-economic effects in relation to the health of local communities and field workers, given that the necessary training and education systems are put into place[62,63] alongside the shifts in pesticide use. For example, more than 50% of pesticides are currently applied by hand-spraying on the field and in many contexts done without the necessary protection equipment or knowledge on the effects of incorrect handling of these chemicals.[64] The Pesticide Action Network (PAN) UK has found through surveys that cotton farming communities in Africa and Central Asia have poisoning rates ranging from 25 to 57% among cotton farmers.[65]

Further along in the value chain, avoiding foul finishing techniques in denim manufacturing such as sandblasting and bleaching can lead to **improved health and safety** in the workplace. The denim industry has already made significant technological advancements in this regard, including but not limited to waterless dyeing techniques, laser finishing and ozone washes.[66] Increasingly, more interest in research and substantiated data on the socio-economic effects of circular economy practices within the textile industry can be seen throughout global news outlets[67,68] and in calls for research proposals and projects.[69] Considering that cotton production employs an estimated 300 million people across the sector,[18] assessing how the employment opportunities in this sector will be affected if there is a decrease in virgin cotton fibre demand[70] is of crucial value. This shift in practice needs to be carefully assessed to ensure that the population suffers the lowest possible negative social impact.

3 ! In the resource extraction phase, the **job opportunities may be either limited or enhanced,** depending on the region's ability to adapt to changes in the value chain structure. For example, if countries across the value chain focused on cotton growing can develop a reprocessing industry for secondary cotton material, this may lead to a shift in the type of jobs available within the country and result in the need for **reskilling workers** for this transition to happen with the lowest possible negative impact.[71] Countries where GDP is highly dependent on cotton growing, but there is no fibre processing industry currently set up (e.g. more than 50% of exports value in Burkina Faso[72]), will face different challenges to adapt to a new value chain setting, in which the EU accounts for roughly 27% of total denim jeans production annually. There could be a shift in the geographies where jobs are available, leading to prospective rural migrations into urban settings.[59] This would entail recycling happening both locally in the EU but also globally across the value chain. Certainly, **migration of workers** needs to be carefully assessed.[59]

Employment opportunities at the manufacturing stage of the value chain should be closely monitored as well, especially for countries with a high degree of employment in the ready-made-garment (RMG) sector. Its relationship with other megatrends such as automation as well as the possibilities to access foreign direct investment and other financing methods, should not be overlooked.[59] In the example of Bangladesh, RMG accounts for 83% of the total exports, in value.[73] Special attention should be placed on the impact on entry level roles and **work opportunities for minorities,** including a significant focus on **informal employment.** Again in Bangladesh 93-98% of workers in the RMG sector that are not in management positions, are informally employed.[74] The shift to more sustainable production processes can in most cases be related to an increase in operational costs in the current scenario,[75] yet the direct link between higher costs and higher wages is still to be further investigated and proven.

MEASURING ENVIRONMENTAL IMPACT: MUD JEANS[76]

Changing the way we design the product can have a significant impact in tackling the negative environmental effects of denim production in cotton growing and manufacturing countries. MUD Jeans is a Dutch-based circular denim brand committed to making good quality, ethical and sustainable jeans available to more people. They are certified as a B Corporation since 2015[77], have a Code of Conduct in place with all suppliers and employees[78]. Further, they have been audited by Fair Wear Foundation in 2016, and have put in place a Corrective Action Plan since then to ensure the necessary improvements were made.

MUD Jeans sources only organic and recycled cotton, have eliminated polluting finishing techniques, reuse around 95% of the water used during the production of jeans and additionally provide repair and leasing services for the product. The close relationship with a reduced number of suppliers is key for them to ensure fair and safe working practices as well as to drive innovation through the value chain.

Between 2015 and 2020, MUD Jeans have conducted two Life Cycle Analysis (LCAs) of their jeans, where the improvement journey towards a product with less negative impact can be observed through improved environmental impact indicators. While the industry average for freshwater consumption of a pair of jeans is 7,000L, in 2016 MUD Jeans was making the same product with 1,500L of water. In 2019, this number has significantly decreased again to 581L for one pair of jeans. Freshwater consumption decrease mainly relates to changes in their cotton sourcing, including the use of recycled cotton; as well as waterless dyeing techniques and the reuse of water at their partner's manufacturing facilities. In relation to CO_2 emissions, where the industry average is 23.45 Kg CO_2 eq, the brand, in 2016 account for 8.88 CO_2 eq per pair of jeans, and in 2019 have managed to lower that amount to 7.14 CO_2 eq mainly due to the use of recycled materials sourced within the EU, the implementation of reusable packaging and the employment of innovative production techniques.

THE DOWNSTREAM SCENARIO: INCREASED AVAILABILITY OF TEXTILES AT THEIR END-OF-USE TO BE REUSED AND RECYCLED

4 ! The growing mountain of textile waste in the EU is mostly being incinerated, landfilled or downcycled.[54] An average of 20-30% is collected separately, giving those resources the opportunity to cycle back into the value chain. Currently, most of the collected textiles are exported abroad, mainly to Eastern European or African countries.[21] When the textiles are suitable for reuse, these feed into a second-hand market within the local economies. In a study for the Nordic Council of Ministers it was estimated that 10,000 market sellers are related to the approximately 12,000 tonnes of Nordic textiles exported to the African continent.[79] An increase in the reuse of textiles locally (R3), an extended lifetime within the EU (R2, R3, R4) as well as increased collection of used textiles (R9) may generate an **impact on international trade and related jobs for second-hand garments.** Denim jeans and textiles that are collected at their end-of-use (R9) and not suitable for reuse may present an opportunity to connect the downstream and upstream value chain through the processing of secondary materials as feedstock for recycling into new products. As mentioned previously, denim offers a substantially homogeneous feedstock that can be reprocessed into new fibre through mechanical and chemical technologies.

POTENTIAL ENVIRONMENTAL EFFECTS

5 ! If the R-strategies are effectively in place, this would **decrease the downstream flow of denim jeans** and thereby **reduce the current negative environmental effects** caused by **dumping of low-quality textiles on landfills** and in the environment, which threatens both human and ecological health. Fast fashion often entails low quality items that are not made to last, resulting in higher volumes of textiles being disposed of rapidly.[54] The effect is compounded through a reduction of synthetic materials, dyes and other chemicals **toxicity,** released from landfilled clothing to land and water.[80] Clothing made from synthetic materials (e.g. denim jeans that include a percentage of polyester or elastane) will likely stay in landfills for 200 years before degrading.[81] Another positive effect would be a **reduction in fires in landfills** that currently are a result of clothing thrown away and handled inappropriately.[79]

It has been repeatedly claimed by a wide range of media outlets that used textiles exported for the global second-hand market are mixed with clothing and textiles that cannot be resold, and therefore end up as **waste in landfill,** causing environmental damage in countries that are not responsible for generating this waste.[82] Therefore, **the need for correct sorting on quality locally within the EU** to prevent low quality or damaged textiles that have no value on the second-hand market from being dumped in low-income countries is key. That will be an important measure to avoid perpetuating negative environmental, and hence socio-economic, effects of exporting used textiles that classify as waste and should not be exported in the first place.[83,84]

POTENTIAL SOCIO-ECONOMIC EFFECTS

Intuitively, a decrease in the textiles exported to second-hand markets globally, could lead to the **decrease in access to income and employment generated around these second-hand markets.** However, it has already been observed that several countries with second-hand markets dependent on US and EU used textile imports are assessing the establishment of used textile import bans (e.g. East African Community (EAC) second-hand clothing ban in Rwanda, Kenya, Uganda, Tanzania, South Sudan and Burundi).[85] This may be due to the interconnection between global second-hand trade markets and **local clothing and traditional, artisanal manufacturing** as well as **local repair shops,** where these industries may **be compromised or driven out of business** due to a large incoming flow of low-priced second-hand clothes for the consumers to purchase.[86] However, other sources claim that the negative impact on local manufacturing would have happened even without second-hand imports, due to the imports of low-priced new clothing from Asia.[79]

Secondly, the current saturation in the second-hand market,[87] as well as the presence of non-reusable or re-sellable clothing and other waste currently exported within bales of second-hand clothing intensify the problem of negatively impacting the labour market.[80] The **quality of work** and the opportunities for decent jobs within the handling of exported used textiles will also be dependent on the access to clothing that is suitable for the second-hand market. This premise makes sorting in the EU between rewearable and non rewearable jeans paramount in order to support **health and safety in the workplace** and avoid waste dumping elsewhere in the world.[70,83,88] This is especially relevant in a sector predominantly staffed by an **informal workforce,** with reported cases of child labour in hand-picking and sorting of textiles for recycling in low and middle-income countries.[89]

Finally, it has been previously discussed that for the purpose of recycling non rewearable jeans, denim offers a substantially **homogeneous feedstock that can be reprocessed** into new fibre through mechanical and chemical technologies. There are currently claims whether denim recycling should happen locally or globally across the value chain.[67,90] While there is no certainty on the future recycling percentages for the EU or other regions, it seems highly unlikely that all recycling will take place locally within the EU when the textile value chain is so highly globalised. What is certain is that with proper sorting in place to identify these non rewearable textiles at the point of generation of these waste, an opportunity arises for them to be sold as feedstock for recycling. Therefore, **new skills** needed to handle these materials will have to be developed and the impact on geographies that will host this recycling industry need to be further assessed, to ensure textiles are handled appropriately and the necessary **infrastructure** can be rolled-out.[91] The strategic and financial support of global brands and retailers, in tandem with local and regional governments will be essential to put these systems in place. Long-term business relationships therefore are enablers to implement these new practices across the value chain.[92]

PROSPECTS FOR USED DENIM AS FEEDSTOCK FOR RECYCLING

The emerging value of denim fabric and finished garments as feedstock for recycling is on the rise. Countries such as India and Turkey have a long-running history in the recycling of cotton textile waste, both downcycling for future uses as, for example industrial cleaning cloths, and increasingly for recycling into new textiles, retaining a higher value. Policy changes have been mirroring changes in industry in relation to denim recycling. For example, in Turkey, the regulation that prohibits imports of used textiles into Turkey, was amended in 2017, to enable the import of a limited number of textile waste products to be used solely as feedstock for the local textile industry in the manufacture of new products for export.[93]

ARVIND LTD.[70]

Arvind Ltd., one of the major denim manufacturers in India, explains that they have been mechanically recycling their own post-industrial denim waste for the past five years. Furthermore, the company has started to look into recycling post-consumer denim waste from regions including the EU, where a portion of textiles is already collected separately. In taking into consideration the globalised nature of a textile value chain, the same broad lens should be applied when considering where recycling should or can take place. Nevertheless, Arvind Ltd. highlights that the correct pre-processing and sorting of used textiles needed before recycling must take place where the waste stream is generated, to ensure that only material that can be reused or reprocessed is shipped across borders.[70]

4 IN FOCUS: MOBILE PHONES

INTRODUCTION TO MOBILE PHONES

In the Netherlands, it is assumed that everyone carries a mobile phone, since payphones are a rare sight today.[94] With a 93% penetration rate (access to or ownership of), the Netherlands also has one of the highest saturation levels for smartphones in the world.[95] The other type of mobile phone is the feature phone, which concerns a small share of the total mobile phone market. Today, the mobile phone is a lightweight option for many different services and functionalities and has dematerialised the average household by consolidating different products (e.g. camera, wallet, street maps) in one portable device. However, Dutch consumers replace their mobile phones with a new version after 2.5 years on average.[96] Despite this, awareness of the negative impacts of raw material extraction for and disposal of mobile phones is rising, so we see developments in the policy and initiative landscape that enable the realisation of a more circular production and consumption system for the mobile phone.

A COMPLEX AND OPAQUE VALUE CHAIN

The mobile phone is a product that "contains almost half of all elements of the periodic table".[97] All materials and components are manufactured in a highly complex and globalised value chain, from resource extraction (where location-specific material deposits are dispersed in resource rich countries across the world), to material processing and component production (with a large number of suppliers involved in production, due to the highly specific expertise required). The many functionalities of the mobile phone require a wide set (400+) of different components (e.g. battery, motherboard, cameras, vibration motor, speakers and a large number or electronic components like capacitors, diodes and varistors).[98] Moreover, to add to the complexity of the value chain, it is notoriously opaque from resource extraction to component production.[99]

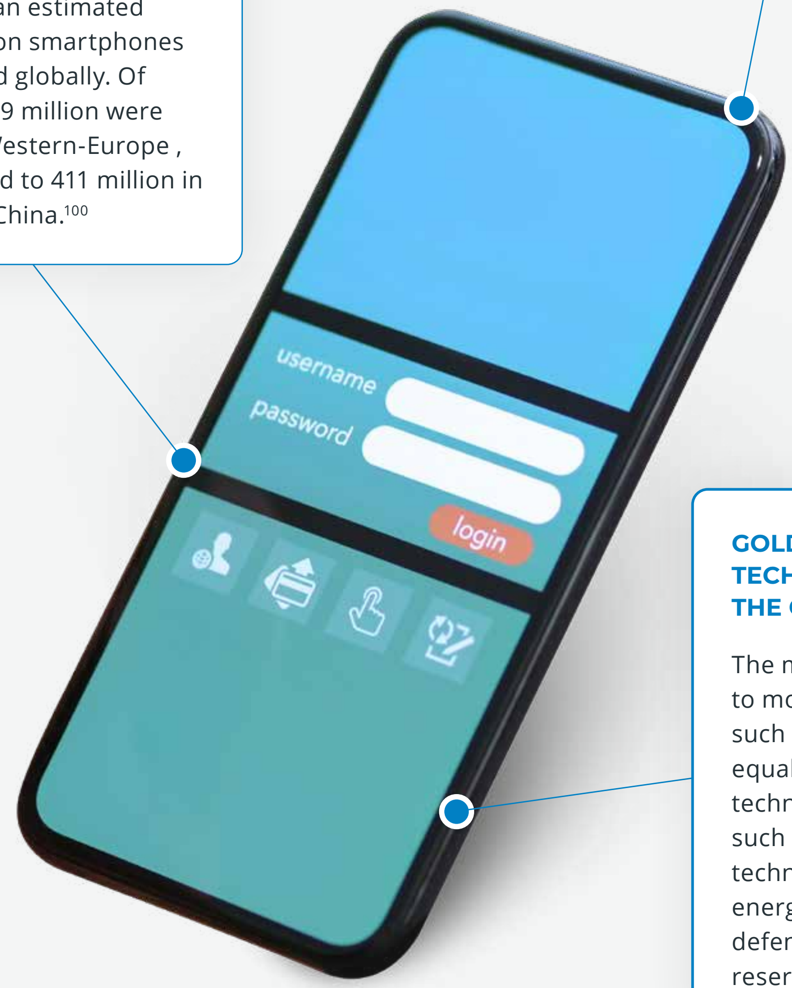
When a mobile phone becomes obsolete to the Dutch consumer, they are either stored indefinitely, end up in the residual waste stream, are taken back by its technology company or are collected through a third party. In the latter case, a share of the phones ends up in recycling within the EU, but another share gets resold (see page 35). The collected phones that are not beyond repair can be sold as used phones in other parts in the world, often low-income countries. However, not all resellers comply with the trade agreement for used phones and end up dumping phones that are beyond repair in these low-income countries, affecting the environment and in doing so the local community (more on page 35). These trade flows are illegal and hard to trace. Similar to the upstream value chain outside the EU, the downstream chain is rather opaque.

23.9 KG OF E-WASTE PER CAPITA IN THE NETHERLANDS (2016)

435 kt of mobile phone waste was generated in 2016, which is 1% from the estimated total global WEEE generation (3.9 Mt out of 44.7 Mt). The average amount of e-waste produced per person in the Netherlands amounted to 23.9 kg, For comparison purposes, this is more than 12 times greater than the average for an inhabitant of the African continent (1.9 kg per person).[101]

GLOBALLY 1.56 BILLION SMARTPHONES SOLD IN 2019

In 2019, an estimated 1.52 billion smartphones were sold globally. Of these, 139 million were sold In Western-Europe , compared to 411 million in Greater China.[100]



GOLD DEMAND FOR TECHNOLOGY IS 7.5% OF THE GLOBAL TOTAL

The metals that are critical to mobile phone technology, such as gold, are often equally critical to other technologies and sectors, such as other consumer technology, renewable energy technologies, national defence equipment, strategic reserves and jewellery.[102]

A SMALL PRODUCT GROUP PART OF ELECTRICAL AND ELECTRONIC EQUIPMENT

In exploring the value chain of mobile phones, it also needs to be recognised that its material, product and waste flows have (inter) dependencies and the product is part of a greater, somewhat modern, product category; electrical and electronic equipment (EEE). This includes any product with a power plug, or battery with circuitry or electrical components, ranging from washing machines and laptops to electric shavers. Mobile phones can be categorised under 'small IT'', which also includes GPS's, calculators and printers.[103] In this analysis, mobile phones are used as an example to get a grip on the subject.

Compared to other EEE, mobile phones are one of the lightest items and therefore are not the only contributor to many problems relating to this category. On the extraction side, ore mining (where most environmental and socio-economic impact takes place) exists to supply not just the production of mobile phones, but also the production of multiple other products. Firstly, demand for new EEE products is growing, with trends like "smart homes", virtual reality technology and personal drones. Secondly, there is a growing demand for the critical metals found in mobile phones due to trends in electrification and renewable energy, with a growing need for e.g. batteries, wind turbines, fuel cells and photovoltaics. Lastly, with a globally growing middle-class, higher consumption of EEE is expected.[103] Aside from other EEE products, some specific materials also play a big role in other markets; for example, the gold demand for technology is only 7.5% of the total demand (including jewellery and gold reserves).[102]

Since consumption of EEE is steadily growing, so is Waste of EEE (WEEE). WEEE, also referred to as e-waste, is dubbed the fastest growing waste stream worldwide and therefore has received increased attention in the last few decades.[104] Compared to other EEE categories, the expected WEEE growth rate for small IT is also one of the slowest due to miniaturisation. According to estimates by the United Nations University, 435 kt of mobile phone waste was generated in 2016, which is 1% from the estimated total global WEEE generation (3.9 Mt out of 44.7 Mt).[103] WEEE monitoring is mostly expressed in weight, which makes it harder to infer the end-of-life scenarios for mobile phones, especially when small devices are much easier to discard in the residual waste, given its size relative to a fridge or vacuum cleaner. However, mobile phones still have a relatively short lifespan and have high material quality demands, therefore it would still be a significant contributor to both resource extraction and WEEE and remains a critical focus area.

THE CURRENT STATE OF THE MOBILE PHONE VALUE CHAIN

A modern mobile phone, the smartphone, roughly weighs anywhere between 130 and 250 grams; 20-25% of that weight is housing, 20-25% battery, 25-30% the display and 25-30% are the other electronic components.[105,98] The approximate material composition is laid out in table 5. Both the upstream and downstream flows of the average mobile phone for Dutch consumption have impacts on the environment and socio-economic landscape in low-income countries. We will discuss the most prevalent negative or positive impacts occurring in the production-consumption system (corresponding visual on pages 36-37.

A RESOURCE INTENSIVE PRODUCT

Large amounts of virgin resources and energy are needed to produce a mobile phone, with accompanying negative environmental and social implications that mainly revolve around the non-abundant precious metals and related mining practices. Despite the small size of a mobile phone, from mining to production there are many more resources used than those that eventually end up in your pocket. For example, roughly 15 kilogram of materials are processed to produce the average 0.03 gram gold content found in smartphones.[108,109] The negative environmental and socio-economic impacts in the mining of the materials is not equally distributed over shear mass either. In fact, it is the **precious metals** - the copper and cobalt, the ~1% of critical raw materials and even the <0.1% of rare earth elements - that cause the greatest impact in resource-rich nation states, both on their populations and on the environment. Each material has a different level of geographical availability, pollution gradation of the mining/processing, technical cycling rate, level of criticality for the production of a mobile phone and so on.[110]

POLLUTIVE AND EXPLOITATIVE MINING PRACTICES

Mining of precious metals is generally accompanied by highly pollutive practices, which makes it an expensive endeavor when living up to high environmental standards. Therefore, mining is more likely executed in low- to middle-income countries that generally have lower compliance to environmental regulations; this is in contrast with mines in resource-rich high-income countries that have been forced to close in the past decades.[111] Low- to middle-income countries commonly display lower quality of environmental governance and are more likely to accept the pollutive mining practices as long as it contributes to the economy. This usually goes hand-in-hand with lower wages and exploitation of workers.[110]

In low income countries, ores are often extracted via informal artisanal and small-scale mining operations (ASM). While large scale mining operations (LSM) are formal, mechanised, capital-intensive with few high-skill workers, ASMs are largely informal operations, labor-intensive, and with a large low-skilled workforce. ASMs supply a significant share of the metals that are critical to mobile phones, such as tin, tantalum and gold (respectively covering 20%, 25% and 26% of the global supply) from countries like Rwanda and Colombia.[112]

ASMs also provides livelihoods to millions in low-income countries. Especially in countries where agriculture and rural activities are becoming less lucrative, ASM provides low-threshold income for those that have few alternative employment opportunities. Over 40 million people work in ASM, of which 9.9 million in sub-Saharan Africa.[112] For some low income countries, mining is a significant contributor to GDP as well (20%, 13% and 6.5% for the Democratic Republic of Congo, Zambia and Ghana respectively).[110]

ASM miners are not aware of the hazardous circumstances in which they are operating, while their work is characterised by high exposure to toxins and poor air quality.[113] In conflict areas, workers are often exploited. Unstable countries rich in minerals like the Democratic Republic of Congo (DRC), can attract organised. The illegal mining operations that produce the so-called “conflict minerals” are using forced labor, including child labor, and enforce little to no safety and health standards.[114]

The operations, both ASM or LSM, cause biodiversity loss by deforestation and soil erosion. Bad environmental practices also result in high ecotoxicity for air, water and soil. Ecotoxicity caused by mining can contaminate the food chain and drinking water, as well as degrade farmland, thereby affecting food production. This causes health issues and limits access to clean drinking water and food.[113] Only the LSMs are required to report on environmental performance, so the full environmental impacts of the ASMs would generally not be reported and monitored.[112] While mining practices are region and mineral-specific, for some mining activities the ASM operations are more harmful to the environment due to the unregulated nature or unintended consequences caused by uneducated workers.[112]

MATERIAL GROUP	MATERIAL	EXAMPLES OF APPLICATIONS
40% METALS	25% steel	Housing
	6% copper	Circuit board, electronic components
	5% cobalt	Li-Ion battery, speaker
	1% critical raw materials (CRM); e.g. gold, tin, tungsten, tantalum	Solder, connectors, electrical components, vibration motor
	< 0.1% rare earth elements (REE); e.g. yttrium, lanthanum, terbium, neodymium	Speaker, vibration motor, camera
	3% other*; e.g. aluminium, lithium, silver, zinc	Electronic components, battery, battery housing
40% PLASTICS	Various types of plastic	Housing, housing of electronic components
20% NON-METALLIC MINERALS	14% glass	Screen
	6% silicon	Electronic components

*Table 5. Approximate material composition breakdown of an archetypical smartphone based on the compilation of multiple studies.[105,98,106,107] *not addressed in visual for sake of simplicity*

DIFFICULTIES CLOSING MATERIAL LOOPS

Apart from base metals (e.g. aluminum, steel), use of recovered precious metals is not yet common practice in mobile phones, due to either high purity requirements or non-economic and non-existent recycling technologies. What is more, even if recycling is technically feasible and economically viable, the supply of recovered materials will almost certainly not meet the projected material demand for production of new mobile phones due to rising demand in a growing global electronics market. In conclusion, at least in the foreseeable future, mining will remain a necessity in the production of mobile phones.[115]

SMELTING, COMPONENT PRODUCTION AND FINAL ASSEMBLY

The value chain between resource extraction and final assembly is highly globalised and complex, making it hard to trace and do due diligence as a final buyer for so many different components. Smelters of the precious ores have locations in every populated continent, while most of the component production and final assembly happens in China.[116] In China, production relies mainly on coal-powered energy. This causes CO_2 emissions, contributing to global warming and acidification, and local air pollution. In addition, in production of the components, there is excessive water use and wastewater containing hazardous materials that, if left untreated, will

CIRCLE ECONOMY

leach into the environment. Air pollution and toxic waste water can cause health issues for the local population that are living around the industry plants.[113]

In 2018, 49% of all exported manufactured phones were from China, making it by far the leading country to produce mobile phones for the global market.[117] The mobile phone industry accounted for 4.7% of all Chinese exports in 2015, contributing to a large share of GDP.[118] China has seen an impressive reduction in poverty between the 1980's and the last decade; from 90% living in poverty according to the World Bank benchmark, to under 2% in 2012. Consumer electronics exports played a main role in this economic boom.[119] While it is acknowledged that China's circumstances are unique and the emergence of a growing middle class are not necessarily replicable in other nations, India, the country with the largest population living below the World Bank's poverty line, could follow a similar path for its emerging phone manufacturing market. According to the Indian Ministry of Electronics and Information Technology, the production value of mobile phones has grown from 3.1 billion dollars in 2015 to 24.3 billion dollars in 2019.[120]

Work in the manufacturing sector is often precarious, with low wages and excessive overtime. Workers can be exposed to toxic substances and generally are not informed about the exposure.[113] However, in producing mobile phones for the EU market, the EU sets the requirements on a limit of hazardous substances (RoHS), contributing to healthier conditions for the workers.

FROM FIRST USE TO EVENTUAL DISCARDING WITHIN THE EU

After being imported by Dutch consumers, the phone will be used by its first user for an average of 2.5 years. During its first lifetime, depending on the model and electricity mix, 10% to 50% of the climate change impacts are contributed through recharging the phone.[98,106] After its first lifetime, the mobile phone will be replaced. According to a survey amongst Dutch consumers, because mobile phones are generally replaced to obtain a technologically advanced model.[121] Also, in case of a broken or underperforming phone, 6 out of 10 Dutch consumers would not consider repair due to the relative high cost in comparison to replacement.[122]

Mobile phones are generally not discarded immediately after their first lifetime. More than half of Dutch consumers state the ambition to give away their phone.[123] However, the actual informal transactions are difficult to quantify.

Roughly half (44% - 60%) of all replaced, out-of-use phones eventually end up in storage.[123,124] Generally, Dutch consumers keep their phones stored as a back-up phone, for potential resale or because they are not sure how to discard it properly.[123] The convenient small size of a mobile phone also makes it more susceptible to be stored and forgotten in drawers. This is creating a large hibernating stock in the drawers in Dutch households. This applies to both broken and functional phones. It is estimated that 15.000 gold rings can be made from roughly 3 million units of stored broken phones in the Netherlands.[122]

Due to owners being ill informed and due to the small size of the product, some phones end up in residual waste meant for incineration rather than recycling; according to surveys, this is around 4-12%.[122,125] The mobile phones ending in the residual waste are a great loss of valuable and critical materials. This unfortunately happens often with small electronic equipment.[126] Other discarded phones enter in a collective or private Collection & Recycling (C&R) scheme. The specific values for mobile phone collection rates can be anywhere between 36% (general e-waste, not mobile phone specific, collection rate in the Netherlands) to a range of 5%-15% based on reports from the official take-back systems.[124] For demonstration purposes, we rounded the limitations to a rough ~ 30% for the visual. What happens after the official and other private take-back systems are also a matter of estimation, as hard numbers are difficult to come by. Breaking down the 30%, there are estimations of ~10% of all phones entering the system eventually are recycled within the EU,[124] ˜10% are exported as second-hand products,[127] leaving ˜10% as unregistered. These unregistered flows concern the unmonitored resold collected phones, of which there are estimations that roughly 30% of that flow is eventually recycled in the EU.[127] Formal recycling of phones in the EU yields high rates for valuable materials (95-98%).[128] Also, some of these unregistered flows are destined for (refurbished) reuse within the Netherlands or the EU, although there are no robust numbers to quantify that flow.

What the system mapping shows are the following main bottlenecks for a circular economy of mobile phones in the Netherlands; high rates for (often indefinite) storage and a significant share of phones discarded into residual waste (both preventing reuse, repair or material recovery), and the general lack of robust data on what happens after collection, thereby hindering monitoring efforts.

REUSE AND END-OF-LIFE OUTSIDE EU

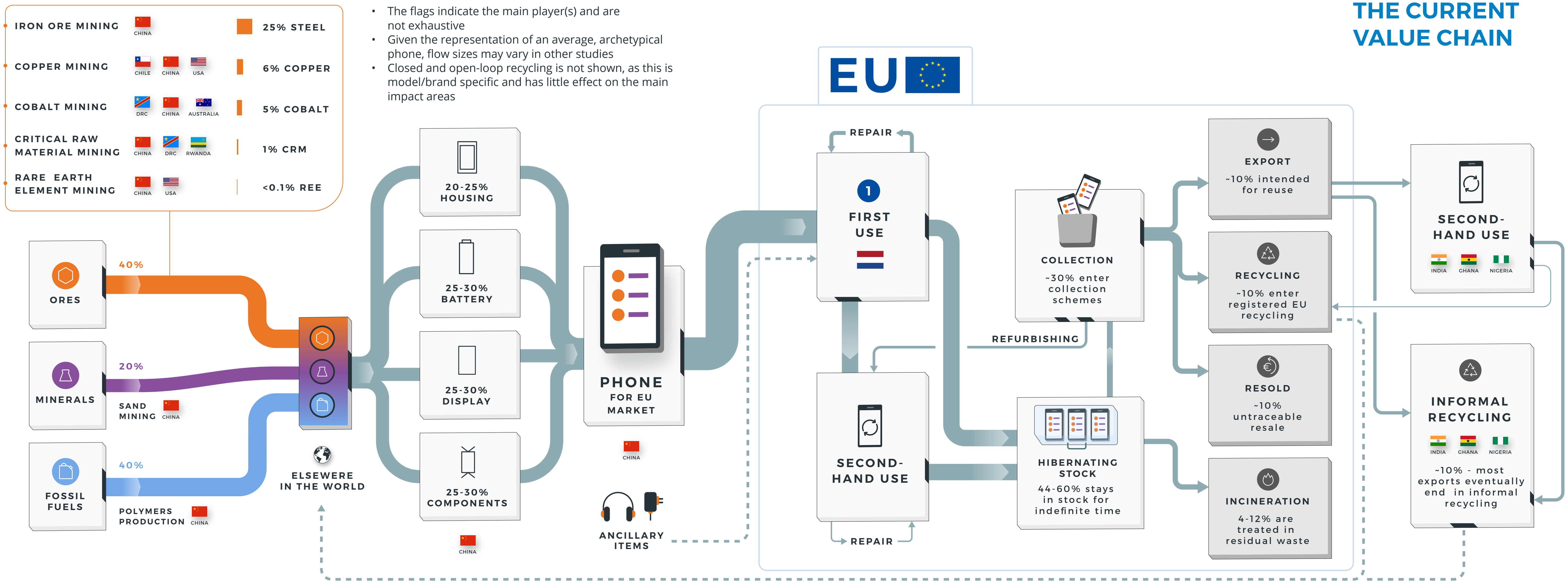
Downstream outside the borders of the EU, there are challenges in the proper recycling of mobile phones and the issues of illegal dumping of waste.

The use of second-hand EU products is encouraged on the basis of circular economy principles. Therefore, discarded phones that can still be used are eligible for export, while exporting phones beyond repair to low-income countries is banned to prevent e-waste dumping. The phones meant for reuse are mainly shipped to Ghana, India and Nigeria.[129] The exported reusable phones have a longer "socio-economic" shelf life in these countries, thereby distributing the initial impacts for producing the phones over a longer lifetime. Phones that are long deemed technologically obsolete in the Netherlands are still widely used in these countries and are generally only replaced when they are beyond repair.[130]

However, these countries have a mostly informal EEE recycling sector, which is unregulated and inefficient.[127] So, a phone that is beyond repair eventually ends up in informal recycling, where e-waste is burnt in an open landfill to retrieve valuable metals. This activity causes hazardous materials to leach into air, soil and water. The ecotoxicity caused by informal e-waste recycling can contaminate the food chain and drinking water, causing health issues in local communities.[113] Informal recycling is often performed by marginalised communities under high health risks. It is unclear how many people work in this sector.[113] While the EU has standards in place to restrict the use of hazardous materials in phones for the EU market, thereby contributing less to the overall ecotoxicity, it is still causing significant harm to the environment and human health.

Because of loopholes in the e-waste export ban treaty, some (economically) irreparable phones are exported and end in the informal waste recycling directly. The export regulation is abused by misclassifying the broken products and incorrect administration.[129] In Nigeria, it is estimated that 0.10 Mt out of the 0.36 Mt e-waste (28%) is directly imported to the landfill.[131]

THE CURRENT VALUE CHAIN



	RESOURCE EXTRACTION	MATERIAL PROCESSING, COMPONENT PRODUCTION AND PHONE MANUFACTURING	FIRST USE TO END-OF-LIFE WITHIN THE EU	REUSE AND END-OF-LIFE OUTSIDE EU
ENVIRONMENTAL	Environmental impacts are concentrated in mining for precious metals. In low-income countries, artisanal and small-scale mining operations (ASM) produce a significant supply of precious metals. Mining operations cause biodiversity loss by deforestation and soil erosion, and bad environmental practices also result in high ecotoxicity for air, water and soil.	The value chain between resource extraction and final assembly is highly globalised and complex. However most of component production and assembly takes place in China, where production relies on coal-powered energy. In production of the components, there is excessive water use and wastewater contains hazardous materials that, if untreated, leach in the environment.	For an average use phase of 2.5 years, 10-50% of the climate change impacts are contributed by recharging. Most phones are indefinitely stored and some phones end up in the residual waste stream. Formal recycling of phones in the EU yields high recycling rates (95-98%). Not all recycling is registered because e-waste can be resold after collection.	The exported phones meant for reuse have a longer “socio-economic” shelf life in countries like Nigeria, thereby distributing the initial impacts over a longer lifetime. Eventually the reused phones end up in informal recycling. Parts of the e-waste are burnt or landfilled, causing hazardous material to leach into air, soil and water. Because of loopholes in the e-waste export ban treaty, some (economically) irreparable phones are exported and end in the informal waste recycling directly, adding to landfill.
SOCIO-ECONOMIC	Over 40 million people work in ASM. Working in ASM is characterised by precarious and unhealthy working conditions with exposure to toxins and poor air quality. Often, especially in conflict areas, workers are exploited. Ecotoxicity caused by mining can contaminate the food chain and drinking water.	The consumer electronics manufacturing industry played a significant role in reducing poverty in China. Factory work is often precarious, with low wages and excessive overtime. Air pollution and toxic waste water can cause health issues for the local population that are based around the industry plants.	In the Netherlands, there is a relatively high replacement rate for the mobile phone, due to a higher sensitivity to trend and the lack of a repair culture. Discarded phones that can still be used are eligible for export, while export of non-functional phones to low-income countries is banned. It is estimated that 15.000 gold rings can be made from all stored defective phones in the Netherlands.	The export of second-hand phones improves access to IT products for poor communities. Informal recycling is often performed by marginalised communities and carries with it high health risks. It is unclear how many people work in this sector. The ecotoxicity caused by informal e-waste recycling can contaminate the food chain and drinking water, causing health issues in local communities.

DUTCH AND EU POLICIES AND INITIATIVES IN SUPPORT OF CIRCULAR MOBILE PHONES

This section of the report provides an (non-exhaustive) inventory of the circular economy initiatives and policies identified in the Netherlands and the EU, that are intended to enable or drive the transition to a circular economy. In the field of initiatives that drive the transition to a circular mobile phone - or more broadly the electronics industry - we have found R-Strategies targeting **rethink, reduce, reuse, repair, refurbish, and recycle** (R1, R2, R3, R4, R5, R8).

EU POLICIES TO SUPPORT THE TRANSITION TO CIRCULAR MOBILE PHONES

Before a mobile phone even enters the EU, there is a clear ambition to enforce and/or expand in EU directives on the design phase; addressing issues with mobile phones and ancillary items that cause them to be obsolete fairly soon from design. The Ecodesign Directive and the Radio Equipment Directive push for **design to last** (R1, R3 and R5) with replaceable batteries and universal chargers respectively.[132,133] Regarding the phone battery, it has a physical shelf life that is far lower than any of the other components, while playing a crucial role in the user experience (often a KPI for the performance of a phone). Allowing accessible replacement of batteries (e.g. replaceable by the user) will extend the lifetime of mobile phones. Next, ancillary items like chargers can also affect the shelf life of a mobile phone when certain items are phased out over time. By tackling these two issues in the design phase, a logical conclusion is that the demand for mobile phones in the Netherlands and EU will decrease, as the required replacement rate will be lower. On the other end, the design phase is steered by the EU's REACH regulations and RoHS directive.[134] By banning (**refusing**; R0) the use of (avoidable) hazardous materials, a higher recycling yield is possible due to lowered to zero contamination of recovered materials.

The Ecodesign directive also expresses the ambition to include secondary material labelling, which gives a notion to which degree a phone has **reduced** (R2) use of virgin material.[132] Some companies, like Apple, already release statements about the secondary or biobased content in their mobile phones. This however usually only pertains to steel, aluminium and plastic contents in the phone and its packaging, which are not the main contributors of socioeconomic and environmental impact areas in developing countries.

For lifetime extension by **repairing** (R4), the EU already requires a 2-year warranty on EEE and the Netherlands even requires warranty within the average expected functional lifetime.[135] Many consumers are not too aware of the Dutch warranty laws, but with further reinforcement and awareness campaigns, this should keep more phones from being discarded too soon. This should also lower the replacement rate of mobile phones in the Netherlands.

Furthermore, there are a few EU interventions to stimulate the recycling (R8) of mobile phones that are put on the market in the EU. Firstly, there is the WEEE directive that sets the ambition for the minimum of discarded EEE (WEEE and obsolete EEE) that needs to be collected through a formal scheme to avoid illegal exports and environmental leaks.[136] The Basel convention restricts export of international hazardous waste such as WEEE (i.e. EEE that is discarded because the product is not economically repairable anymore), since the WEEE is likely to end up dumped in an open landfill in low-income countries like Ghana, Nigeria and Bangladesh.[129] This restriction has been in place since 1992, but it is estimated that still 1.3 million tonnes of WEEE is exported from the EU to low-income countries.[10] While it is encouraged to export second-hand EEE that is useful to low-income country populations, monitoring this stream has proven difficult. WEEE is often misclassified as potentially useful EEE, when either this is not the case or there is simply not a market anymore for this type of EEE product. Reporting obligations on the (W)EEE streams are also not followed (correctly) by different country administrations. Lastly, there is a complex network in place to ship WEEE towards the low-income end destinations undetected.[101] The ineffectiveness of the WEEE export ban could bring the export of second-hand EEE into legislative uncertainty.[129]

All these directives and policies combined, together with the initiatives, will have an effect on the demand for mobile phones for the Dutch market (affecting upstream impact areas). They also affect the flow of phones used by Dutch consumers that are exported to developing countries (affecting downstream impact areas).

Table 6 provides an overview of relevant policies and directives in the EU, targeting the EEE sector.

STRATEGY		POLICIES
R0	**Refuse**	EU - REACH & RoHS - Restriction hazardous material use
R1	**Rethink**	EU - Radio Equipment Directive "One charger for all"
R2	**Reduce**	*EU - Ecodesign directive a) secondary material labelling*
R3	*Reuse*	*EU - Ecodesign directive* b) small EEE design to last
R4	**Repair**	EU - 2y warrantee EEE NL - EEE warranty until expected lifetime *EU - ecodesign directive c) replaceable batteries* EU - CENELEC WEEE mgmt standards
R5	**Refurbish**	*EU - Ecodesign directive b) small EEE design to last*
R6	**Remanufacture**	
R7	**Repurpose**	
R8	**Recycle**	EU - REACH/RoHS - increasing inherent circularity EU - WEEE directive - WEEE collection targets + obligation to collect (Dutch: inzamelplicht) large retailers EU - Basel convention - restriction of WEEE exports EU - CENELEC WEEE management standards
R9	**Recover**	

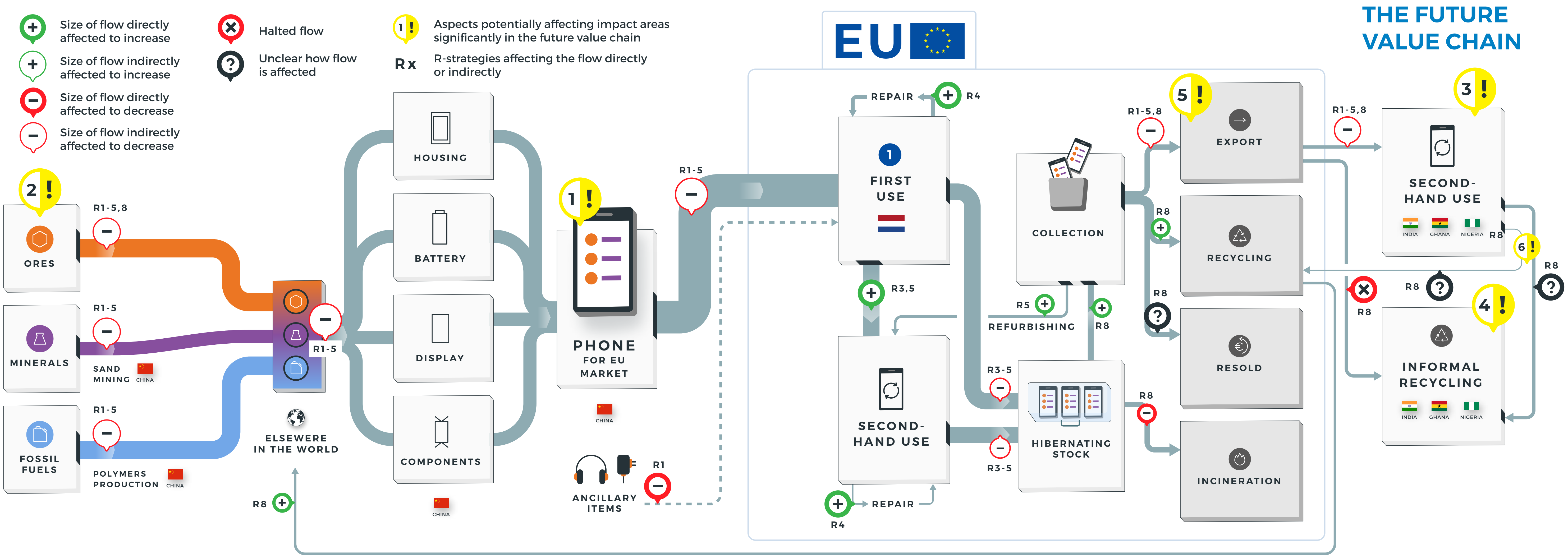
Table 6. Dutch and EU policies that support the transition to the circular economy for electronics. Italic = recommended in official policy documentation; EU = implemented on an EU level; NL: Implemented in the Netherlands

PRIVATE INITIATIVES TO SUPPORT AND SCALE THE TRANSITION TO CIRCULAR MOBILE PHONES

Table 7 (see next page). shows a non-exhaustive list of examples of initiatives by private actors. There is growing momentum in driving towards a vision of circular mobile phones, with Dutch social enterprises Fairphone and Closing the Loop as a leading example (see page 45 and 47 for more details).

STRATEGY		INITIATIVES
R0	**Refuse**	
R1	**Rethink**	NL - Fairphone - modular phones
R2	**Reduce**	World - Apple, Fairphone - secondary material use and closed loop recycling reported by manufacturer in environmental product declarations
R3	*Reuse*	NL - Marktplaats and ReBuy - peer-to-peer second-hand sales platforms
R4	**Repair**	NL - Fairphone - modular phones, NL - Repair café - World - iFixit, Right to Repair movement
R5	**Refurbish**	NL - Leapp, SWOOP - IT electronics refurbishing companies
R6	**Remanufacture**	
R7	**Repurpose**	
R8	**Recycle**	NL - Closing the Loop - avoiding adding to landfill by buying wasted phones in low-developing countries and ensuring proper recycling NL - Nowa, gold and silver jewelry extracted from old mobile phones NL - Privately funded collective C&R schemes Wecycle & WEEE-NL (EPR) EU - Umicore - state-of-the art recycler with high recovery yield for precious metals
R9	**Recover**	

Table 7. Non-exhaustive list of Private initiatives to support the transition to the circular economy for mobile phones. EU = implemented on an EU level; NL: Implemented in the Netherlands



EXPLORING POTENTIAL GLOBAL EFFECTS OF EU CIRCULAR ELECTRONICS STRATEGIES

Using thought experiments that build on the current state visual and the underlying data, we imagine a circular economy for mobile phones according to the expressed ambitions in EU and Dutch policy. First, we can hypothesise on the generally expected effects and how they might affect the identified impact areas. Given that the mobile phone production and consumption system for the Dutch market is part of a much larger and complex ecosystem, we tested the hypotheses with experts in the field to also consider the influence of external factors and relevant macrotrends, as well as to gain insights in on-the-ground examples and challenges.

The visual above demonstrates the changes to the flows as well as the R-strategies that cause these changes, in a simplified manner. The aspects in the value chain that affect or are affecting the socio-economic and environmental impact areas significantly are highlighted. The details of the effects will be discussed on the next pages.

Upstream. For the mobile phone, the main targeted effects of the R-strategies combined are a reduction in demand for mobile phones in the local market, thereby reducing imports to the Netherlands. This trickles down to a reduction in activity in mining, processing and manufacturing for phones meant for the Dutch market.

Downstream. On the downstream side, the current strategies reduce or potentially even halt export of second-hand phones and related e-waste products to low-income countries by extending the lifetimes of the phones significantly and achieving high WEEE collection and recycling targets within the Netherlands and EU.

1 ! A reduction in manufacturing activity in Asia could also reduce the number of low-threshold jobs that could pull many out of poverty.

2 ! Artisanal and small scale mining provides a livelihood to many that have few other employment opportunities. A reduced demand for mining would mean a loss of income or causing a shift to unknown alternative forms of income.

3 ! A reduction or complete stop of second-hand phone exports could reduce access to high-quality IT products for poor communities.

4 ! Alternative second-hand phones might be less durable and contain more hazardous materials, causing more hazardous substances to leak into the environment more often in its eventual local informal recycling.

5 ! In current policies and targets, focus is set on the mobile phone lifecycles in the EU itself, the extended lifetimes experienced in the export countries, including its potential environmental and socio-economic benefits, are not taken into account.

6 ! Importing waste for recycling from countries with informal and destructive recycling practices lacks clear regulations.

THE UPSTREAM SCENARIO:
PROSPECTS FOR A REDUCED DEMAND OF NEW MOBILE PHONES IN THE NETHERLANDS

When the mobile phone for the Dutch market has a much longer lifespan, achieved with design for repair, encouraging reuse and through remanufacturing, there will be a much lower replacement rate than the Netherlands currently upholds. In isolation from external factors, this will **decrease imports** from the manufacturing countries, mainly China and India, and furthermore **decrease all other activities upstream** towards resource extraction activities that are necessary to manufacture new phones for the Dutch market.

POTENTIAL ENVIRONMENTAL EFFECTS

For China, mobile phones and the associated components are a significant contributor to the country's exports, but also a significant contributor to **local pollution (ecotoxicity) and global warming** (running the industry on coal-fired power). A reduction in production activity would then lead to **fewer emissions** and a reduced need for coal-fired power. In mining, following a reduced need for resource extraction, **environmentally destructive practices could be abated.** Generally speaking, both ASM and industrial mining are associated with destroying local ecosystems rich in biodiversity, for example in Ghana, Nigeria and the Central African region, through deforestation. As a positive result of a decrease in virgin material sourcing, the land can be reclaimed by nature.[113]

POTENTIAL SOCIO-ECONOMIC EFFECTS

An overall decrease in the phone manufacturing activity could mean there will be less precarious jobs that often involve excessive overtime.[113]

1 ! As explained on page 34, the EEE manufacturing industry could boost India's economy and can provide **low-threshold jobs** that can potentially lift many of its poor citizens **out of poverty.** Would a circular economy reduce the yearly demand for manufactured phones, so would it reduce the potential of creating jobs in the country with the biggest population living in poverty.

On the side of resource extraction, a reduced demand for critical metals could cause a **loss in exploitative and dangerous ASM mining jobs.**

2 ! At the same time, the ASMs provide a livelihood to many that have few other employment opportunities.[112] Especially in countries that suffer from weak administration and where resource rich areas are ruled by conflict groups, the alternative sources of income are unclear and might lead to vulnerable groups joining these conflict groups.[115]

REALITY OF THE GROWING DEMAND IN OTHER REGIONS AND THE MULTIFUNCTIONAL UPSTREAM VALUE CHAIN

As laid out in page 29, mobile phones destined for the EU market are a small share of the total mobile phone market. The rapidly developing countries are showing steep consumption growth rates for mobile phones and EEE in general, therefore it is expected that the growing global demand for EEE will continue to increase the need for manufacturing and resource mining, despite circular economy efforts in the Netherlands or the EU. Also, the precious metals are not solely mined for the production of mobile phones; they will also need to satisfy the growing demand for specialty metals in renewable energy technologies and electrification.

This need for precious metals will continue to grow both the ASM and LSM activities in resource-rich low-income countries, as well as the manufacturing operations in India and other emerging economies. Therefore, it is highly recommended to focus on responsible mining and manufacturing practices, by stimulating healthy and safe working conditions that are environmentally sound.[115] In the mining sector this can translate to the formalisation of ASMs, whereas in manufacturing this could take the form of the freedom to unionise.[112,113,137]

FAIRPHONE: TOWARDS A CIRCULAR MOBILE PHONE

Fairphone is a Dutch social enterprise that inspires sustainable change in the electronics industry. The company uses the development and marketing of its phones to drive awareness change, provide the example and enable industry action in four key pillars: long-lasting design, fair materials, good working conditions, and reuse & recycling. A modular phone was adopted to ensure long-lasting and circular design. Modularity makes the Fairphone easy to repair for customers and partners.

An LCA analysis performed on the Fairphone 2 estimates it has an environmental impact of 44 kg CO_2e. This compares to an iPhone SE with similar memory (32GB) and 45.0 kg CO_2e. The newest model, iPhone 11 Pro has an impact of 80 kg CO_2e. The production phase is the main contributor, mostly more than 75% of total impact. Both the use phase and transportation have a limited impact, and recycling at end-of-life has a positive impact. In comparison, the modular design of the Fairphone has the potential to reduce climate impact by 28% per year in use, based on a repair scenario that extends the lifetime from three to five years.[138,139,140]

On the social side, Fairphone drives initiatives in the upstream value chain to reduce negative social impacts. For example, sourcing conflict-free minerals through working with local projects in countries with mining activities, such as the Solutions for Hope project in DRC. A pilot conducted in 2012 demonstrated the potential to increase miner wages, with materials selling at global market rates.[113,137]

THE DOWNSTREAM SCENARIO:
PROSPECTS FOR DOWNSTREAM COUNTRIES WHEN THE DUTCH REPLACEMENT RATE SLOWS DOWN AND RECYCLING GOES UP

One of the first logical consequences of a reduction in the supply of used and broken phones to the sub-Saharan African countries, most notably Nigeria and Ghana, and Southern Asia would mean an equal reduction of phones discarded by Dutch consumers to eventually end up in open landfills (after a potential second use phase in the downstream countries).

POTENTIAL ENVIRONMENTAL EFFECTS

In isolation from other external factors, a reduced stream of mobile phones to low-income countries would mean that the negative environmental impacts from informal e-waste treatment are mitigated; in other words, it would contribute to **less ecotoxicity** in downstream countries resulting, for example from burning practices to extract metals, which would in turn **improve the quality of the soil, water and air.**

POTENTIAL SOCIO-ECONOMIC EFFECTS

A potential reduction in informal e-waste treatment or landfilling would also affect the social impact areas positively, as it **reduces food chain and drinking water pollution, increases agricultural yields and is beneficial to the health of local communities.** Yet possible negative social effects might include the **loss of income from informal waste mining.** However, this income is associated with precarious work.[113] For a proper judgement of the negative impact, the alternative to this job is unknown (e.g. higher or lower quality job, unemployment).

3 ! A second logical consequence would be a decreased or halted stream of useful phones discarded by Dutch consumers that would otherwise have an extended lifetime in low-income countries. This could cause **lower accessibility** to mobile phones for poor populations in these countries, there by **reducing their connectivity and access to digital services** such as banking, education and healthcare that may lift them out of poverty. It is estimated that there are half a million jobs related to the mobile phone ecosystem in Sub-Saharan Africa in 2018, plus 1.2 million more informal jobs.[141]

REALITY OF THE SECOND-HAND ALTERNATIVE IN LIEU OF SECOND HAND MOBILE PHONES FROM THE NETHERLANDS

However, we will need to take external factors into consideration as well. Having consulted Closing the Loop, we learned that the intended beneficial effects of policies and initiatives aimed at circularity for mobile phones might actually cause a rebound effect in low-income countries, due to an accompanying growing influx of **lower quality mobile phones** to meet growing demand. These phones would replace second-hand mobile phones that comply with high quality standards required for the Dutch market.

4 ! In contrast to mobile phones destined for the Chinese market, mobile phones destined for the EU market must comply with higher design standards; the high EU warranty standards that stimulate high quality design and the restriction of use of hazardous materials. Substituting the Dutch used mobile phones by (probably) lower quality mobile phones manufactured for markets with lower standards on durability and hazardous materials, means that the phones might break faster and are harder to repair. and with its eventual landfilling, The potentially higher landfilling rate of these phones, that could also contain more hazardous materials, would cause **more hazardous substances to leak into the environment more often.**[130] This would likely exacerbate current socioeconomic impacts related to informal e-waste treatment, such as **food and water pollution and other forms of human toxicity.**

3 ! A less severe, yet mentionable, issue arising from replacing EU market phones is the **lower quality** of the alternative phones, since the alternatives are more likely to be mid- to low-range models. In contrast, the EU mobile phone market is characterised by high-end, often flagship, models with higher performance. This implies that mobile phones from the EU have more reuse value and potential, since they will last longer, thereby supporting connectivity and access to digital service.

5 ! The targets set by the WEEE directive also miss the potential for extended use of mobile phones in low-income countries. The directive's targets are set on the mobile phone lifecycles in the EU itself, the **extended lifetimes** experienced in the export countries **are not taken into account** in the models that have informed these targets. This ignores the fact that the product lifecycle in the relevant downstream countries is much slower than in the EU (e.g. a phone that is already deemed obsolete in the EU, such as a feature phone, is still used by consumers in low-income countries) and that there is a more developed "phone repairing culture" than in the Netherlands and EU. When accounting for the potential extended use in developing countries, it becomes clear that there is an environmental and socio-economic trade-off between ensuring proper recycling locally and lifetime extension elsewhere. It warrants further research to investigate which of the strategies demonstrates the most net-beneficial effects.

6 ! Closing the Loop recognises these aforementioned negative environmental and socio-economic rebound effects and buys e-waste from local communities to import back into the EU for proper recycling. Since **importing waste** into the EU is controversial and **lacks clear regulations,** it can take over a year to get the permission to ship the e-waste back into the EU, to then be recycled at Umicore (Belgium) and Sims Lifecycle Services (Netherlands).[130]

CHALLENGING THE REBOUND EFFECTS

Due to the likely environmental rebound effect from a higher landfilling rate in the substitution of EU second-hand phones with lower quality phones produced with more hazardous materials, exploring opportunities for a more circular mobile phone would be more environmentally sustainable. One for which recycling targets are not only set within geographical boundaries but will also include the extended use of high-quality phones elsewhere. This should be followed by recycling in the EU or by supporting the development of a formal recycling sector in the relevant countries. Given the clear difference in consumer culture, the Netherlands (and other EU countries) and their low-income counterparts might have a symbiotic relationship, where the consumer from high-income countries can have the newest high quality phones "guilt free" and through passing on the older model to low-income countries, enable an extended use phase and provide consumers in those countries with high quality phones for an accessible price. For this reason, the main efforts should potentially not be in reuse, repair, and refurbishment within the EU only, since this would ask a large degree of behavioural change from Dutch consumers, likely with a high level of communication efforts against marginal effect. In short, due to the high lifetime extension in the countries importing second-hand phones, the focus should not only be on extending the lifetime of phones in the Netherlands or the EU.

CLOSING THE LOOP: AN IMPACTFUL AND INCLUSIVE APPROACH TO E-WASTE COLLECTION IN AFRICA

Currently, proper and safe recycling facilities are lacking in countries where the majority of e-waste ends up. It is largely managed by an informal, unregulated recycling sector with associated environmental pollution and health risks. A formal system is lacking due to the high upfront investment cost of recycling facilities and the absence of collection infrastructures, legislation and consumer awareness. Therefore, Closing the Loop offers an e-waste offsetting service; it compensates electronic purchases of its customers through collecting an equivalent amount of end-of-life mobile phones in African countries. These are then shipped to proper recycling facilities (e.g. in Europe).

However, the business case to recycle where e-waste is mounting makes sense both socially and environmentally. Local recycling facilities will provide work and income, that is more safe and healthier. It will prevent more hazardous chemicals leaking into water and soil.[130] Moreover, the recovered materials can be used to make the production process of mobile phones more sustainable, similar to what happens now via Closing the Loop's European recycling partners.

There is an opportunity for the EU to play a role in combating a rapidly growing issue and take responsibility for a part of the problem it has helped to create, via exports of million tons of used mobile phones and other e-waste outside of Europe. For example through investing 'disposal fees' (verwijderingsbijdrage in Dutch), to encourage adoption of e-waste compensation (e.g TCO Certified Edge),[142] or to include (African) e-waste collection to reach EU recycling targets. In the New Circular Economy Action Plan the EU states it will support measures including improvement of sustainable waste management in countries to which waste has been exported.[143] However, working with local governments on this – and ensuring the connected legislation is implemented - have proven to be difficult. Until progress has been made on local waste management, a key requirement will be to pay collectors a higher price for e-waste than the price offered by the illegal recycling industry. Here, an innovative organisation such as Closing the Loop can bridge the gap between current African reality and future EU plans.

5 CONCLUSION & WAY FORWARD

Pursuing a circular economy in the Netherlands or EU will have global effects, and these effects may be both positive and negative. In this report we assessed the current level of knowledge of the effects of circular economy initiatives on global supply chains, with a focus on the socio-economic and environmental effects for low-income countries. This report presents a deep dive into the denim jeans and mobile phones value chain and sought to identify the main environmental and socio-economic impact areas in current value chains and explored potential effects in low-income countries assuming Dutch and EU circular policies are in place. Below we will present the outcomes of our analysis of these value chains and in the next chapter, we will describe the knowledge gaps that we have encountered and suggest areas for future research.

CURRENT RESEARCH SUGGESTS POSITIVE EFFECTS FOR THE ENVIRONMENT AND HEALTH AND NEGATIVE IMPACTS ON WORK AND INCOME

What surfaces from both analyses, is that the expected effects for the jeans and mobile phone industries are largely positive from an environmental and health perspective, in the scenarios we have outlined. This conclusion results from the targeted reduction in demand for virgin materials if recycled content increases or an overall reduction in product demand if the use phases are extended. The same holds true for the end of the value chain: extended lifecycles in the Netherlands would diminish export of used products which would otherwise end up in improper waste treatment. All other things equal, current negative effects, such as water stress, pollution of water and soil, the health issues related to pollution and CO_2 emissions, should diminish.

From the work and income perspective, effects are to be monitored closely, since these can be expected to be negative. This would be the consequence of a reduction in jobs associated with upstream and downstream activities that will change. However, depending on e.g. the location of recycling or reprocessing facilities, it could mean a shift in type of jobs required, that could imply the need for reskilling of workers. Also, when there currently is a significant market for the exported used products as second hand goods, it is necessary to be cognisant of the alternative, possibly lower quality products that would satisfy this demand instead. The case study for mobile phones shows that the alternative could cause more harm to the locals and their environment.

In all cases, the interdependence of value chains, the global economy and the recurrent vulnerabilities of low-income countries in these contexts are evident in the available literature. Further, in trying to understand the potential effects that might take place, various types of knowledge gaps surfaced. Therefore, potential effects are in essence explorations of potential scenarios, and additional data or more in-depth analysis could alter the conclusions.

POLICY MEASURES AND CIRCULAR ECONOMY INITIATIVES NEED TO BE TAILORED TO SPECIFIC CONTEXTS

Having visualised the material and product flows in combination with a geographical perspective, we can see that each value chain has its specific challenges; from pollutive resource extraction and manufacturing processes, to low standards of health and safety and low-income jobs. At the same time, we have mapped a multitude of circular economy strategies, both active and foreseen to be implemented, from the Netherlands or the EU. However, it was not always clear how a (combination of) policies and initiatives formulated for the European context might impact the highlighted environmental and socio-economic areas of concern. Although the deep dives into both product groups have proven useful to understand the full picture of global value chains, the relatively small shares of denim jeans and mobile phones in the respective broader product categories of textiles and electronics often made it difficult to analyse potential effects of changes. An important reason is that the effects are highly dependent on global developments and interactions with similar, intertwined value chains. Moreover, some of the efforts in circularity within the Netherlands could have little to no significant impact on a global scale. Even if we would extend our scope towards a circular economy in the EU, a possible decline in economic activity to serve the EU market could be cancelled out by global dynamics and macro trends.

To illustrate, for example, for mobile phones the upstream effects related to resource extraction are highly dependent on the development of demand for the broader EEE category it is a part of. Even in the hypothetical situation that mobile phones could be produced with 100% secondary materials, the expected steep demand for these types of products and materials will likely require mining for the foreseeable future.

For denim jeans, the downstream effects of increased reuse and recycling percentages in the EU are still uncertain and policies in this regard are not yet implemented. This is further augmented by uncertainty on how the value chain will be reconfigured globally, e.g. where recycling facilities will be located in a highly globalised value chain. While recycling locally would enable a decrease in CO_2 emissions related to transportation and secure increased employment opportunities in this sector locally in the EU, a formal recycling industry in regions closer to extraction and production locations might enable transition of workers from the informal sector, while enabling scale of operations close to manufacturing facilities.

To summarise, even though effects are highly context-specific, the deep dives in the value chains in scope and reflections from the experts interviewed brought forward the relevance of zooming in and out from specific products and local context, to wider industry and global trends to put findings and hypotheses into perspective. The implications are not a simple and straightforward analysis of 'A triggers B', yet requires a careful assessment and consideration of unexpected side effects and interactions with macroeconomic trends. An example that surfaced from the analysis is the possible replacement of second-hand phones from the EU market with phones that do not have to comply with the high environmental, health and durability EU standards. Or, the dependency on technological developments for recycling of denim jeans, as currently chemical recycling technologies are very limited in scale but are expected to have a large and disruptive impact in the textile recycling sector over the coming decade.

POLICY RECOMMENDATIONS

The conclusions informed a number of policy recommendations targeted at the upstream or downstream activities.

On the upstream, it is recommended to take into account a global perspective and broader market development trends driven by population growth and an increasing rise of middle-income households that may influence demand for products in emerging and low-income economies, and thereby demand for raw materials. The Dutch and EU market share is relatively limited compared to global demand and might have a limited influence on changing current, often environmentally detrimental and socially hazardous, practices. For example, with the current market dynamic, where demand for precious metals would overshadow supply of recycled metals due to the lack of economic material recovery technologies, recycling will not be the main strategy towards a more circular mobile phone. Therefore, it is highly recommended to also focus on responsible mining practices, by stimulating healthy and safe working conditions that are environmentally sound. Or, if recycled content for denim jeans is increased significantly, the impact on cotton farmers should be taken into account if their crop becomes obsolete. The policies should take into account alternative forms of income for vulnerable smallholder farmers, to prevent a shift of one unsustainable farming practice to the other.

Secondly, it is recommended to carefully design an approach that considers extending the useful life of products in low-income countries, compared to the EU. Specifically for mobile phones, due to the high potential for lifetime extension in low-income countries with a strong demand for this product, the focus should not only be on extending the lifetime in the Netherlands or the EU.

At the end-of-life stage, the impact of increased collection rates and local (EU) reuse and recycling targets needs to be assessed to understand the best way to move forward with policy setting, whilst mitigating any potential negative rebound effects across the wider value chain. Here, it is recommended to take into consideration the most suitable location to invest in recycling facilities. Insights from this exploratory study indicate this could have the most impact in countries where waste is posing a significant threat to the environment, e.g. through ecotoxicity, and relatedly negatively impacts the health and safety of communities living around landfills or working in informal waste management jobs.

AREAS FOR FUTURE RESEARCH

As a final step, we summarise the insights provided by the current analysis and the need for extra knowledge, data and research that surfaced in conducting this study.

The most prevalent gap that surfaced is a lack in transparency in both value chains under study, especially for the mobile phone value chain, which has a notoriously opaque and complex value chain, with many players. Moreover, data is not always up to date or at the level of granularity wished for in a context-specific analysis, e.g. specific data on denim waste stream (types and volumes ending up in landfill). Nor is it always clear how many people are employed in both sectors, especially in informal waste management, or in informal mining. The data analysis is based on data we have access to. Potentially there is data (from outside the EU) that is not known or available to us. Alternatively, it could be that data is not available yet and provides an area for global collaboration, more specifically on data collection, standardisation and sharing of data for further research.

Another gap is a lack of quantitative research on the potential trade-offs and impacts related to circular economy policies. Examples of research areas that would be valuable are, on the environmental side, the comparison between informal recycling after additional lifetime versus one lifetime followed by proper recycling. On the socio-economic side, research would be required that provides an analysis of the interrelation of the number of jobs impacted and quality of work.

What surfaced from conversations with experts is a gap in - and need for - public-private collaboration (as stated in the Circular Economy Action Plan). Collaboration could enable existing initiatives (e.g. to finance local, formal recycling facilities in low-income countries) and could complement research with on-the-ground examples. In turn, that will enable informed policy development processes, especially related to Dutch and EU circular economy policies intended to drive positive effects in low-income countries.

Finally, we highlight cultural gaps that seem to be a blind spot in current research approaches. Research is conducted from a country perspective, including embedded cultural values in relation to work. An example is the fact that old feature phones, that are believed to have basically no value in the Netherlands (other than maybe its material value), are still very useful and valuable to communities in certain low-income countries. We would recommend bringing together worldwide research efforts to make context-specific analysis context-relevant.

SUGGESTED POTENTIAL AREAS FOR FURTHER STUDY INCLUDE:

- An assessment of employment opportunities if demand for virgin materials decreases; what will be the alternative to jobs currently associated with virgin material extraction or production? (e.g. will there be a shift to lower quality jobs or even unemployment, or will this effect stimulate decent jobs creation. What will be the effect on informal sectors?);
- Qualitative and longitudinal impact assessment on local communities, to assess potential effects over a longer period of time;
- Research on opportunities for local or regional recycling, to close resource loops closer to home, both in the Dutch and low-income country context. Yet at the same time it seems highly unlikely that all recycling will take place locally within the EU when value chains are so highly globalised. For a proper judgement on the negative impact, it is advised to explore the development of a formal recycling sector in the relevant countries.

Finally, Circle Economy would recommend further consultation with a broader group of stakeholders representing the full spectrum of actors in the value chains researched to elaborate on the findings in this report. Bringing together wider viewpoints can contribute to a more detailed view of the complex nature of these value chains, enhancing both transparency and triggering much needed collaboration to increase the potential positive effects and mitigate the unintended negative effects of a transition to a circular economy. A sustainable future can become reality if we apply the concept of the circular economy to collectively reimagine and redesign our systems to ensure a safe and just space for us all, which respects and treasures the natural environment.

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EXPERT REFLECTIONS

In the development of this report, Circle Economy consulted an independent panel of experts in the fields of sustainability and circular economy within the respective sectors researched. The panel, during bi-lateral interviews, provided insights into current industry challenges, knowledge gaps, relevant studies and on-the-ground examples.

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