ELLEN MACARTHUR FOUNDATION
Rethink the future

2013

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TOWARDS THE CIRCULAR ECONOMY

Economic and business rationale for an accelerated transition

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Acknowledgements

The Ellen MacArthur Foundation was formed in 2010 to inspire a generation to rethink, redesign and build a positive future. The Foundation believes that the circular economy provides a coherent framework for systems level redesign and as such offers us an opportunity to harness innovation and creativity to enable a positive, restorative economy.

The Foundation is supported by a group of 'Founding Partners'—**B&Q, BT, Cisco, National Grid and Renault.** Each of these organisations has been instrumental in the initial formation of the Foundation, the instigation of this report and continues to support its activities in education, communications and working as a business catalyst.

McKinsey & Company, a global management consulting firm, provided the overall project management, developed the fact base and delivered the analytics for the report.

In addition to a number of leading academic and industry experts, an extended group of organisations provided input and expertise. They included **Caterpillar, Cyberpac, Desso, EPEA, Foresight Group, ISE, Marks & Spencer, Product-Life Institute, Ricoh, Turntoo, and Vestas.**

Foreword

An opportunity to rethink our economic future

The Ellen MacArthur Foundation's report on the Economics of a Circular Economy invites readers to imagine an economy in which today's goods are tomorrow's resources, forming a virtuous cycle that fosters prosperity in a world of finite resources.

This change in perspective is important to address many of today's fundamental challenges. Traditional linear consumption patterns ('take-make-dispose') are coming up against constraints on the availability of resources. The challenges on the resource side are compounded by rising demand from the world's growing and increasingly affluent population. As a result, we are observing unsustainable overuse of resources, higher price levels, and more volatility in many markets.

As part of our strategy for Europe 2020, the European Commission has chosen to respond to these challenges by moving to a more restorative economic system that drives substantial and lasting improvements of our resource productivity. It is our choice how, and how fast, we want to manage this inevitable transition. Good policy offers short- and long-term economic, social, and environmental benefits. But success in increasing our overall resilience ultimately depends on the private sector's ability to adopt and profitably develop the relevant new business models.

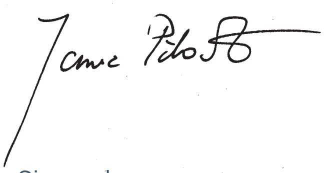
The Foundation's report paints a clear picture: our linear 'take-make-dispose' approach is leading to scarcity, volatility, and pricing levels that are unaffordable for our economy's manufacturing base.

As a compelling response to these challenges, the report advocates the adoption of the circular economy, and provides an array of case examples, a solid framework, and a few guiding principles for doing so. Through analysis of a number of specific examples, the research also highlights immediate and relatively easy-to-implement opportunities. On the basis of current technologies and trends, it derives an estimate of the net material cost saving benefits of adopting a more restorative approach—more than USD 600 billion p.a. by 2025, net of material costs incurred during reverse-cycle activities. The corresponding shift towards buying and selling 'performance' and designing products for regeneration should also spur positive secondary effects such as a wave of innovations and employment in growth sectors of the economy, whilst increasing Europe's competitiveness in the global marketplace. Many business leaders believe the innovation challenge of the century will be to foster prosperity in a world of finite resources. Coming up with answers to this challenge will create competitive advantage.

While The Foundation's first report has taken a European perspective, I believe that its lessons are relevant at a global level. It will not be possible for developing economies to share the developed world's level of living standards and provide for future generations unless we dramatically change the way we run our global economy.

The Foundation's report offers a fresh perspective on what a transition path to a circular economy at global scale could look like. It is time to 'mainstream' the circular economy as a credible, powerful, and lasting answer to our current and future growth and resource challenges.

As you read the report, I urge you to consider where and how you can contribute to jointly moving towards a new era of economic opportunity.



Sincerely,
Janez Potočnik
European Commissoner for the Environment

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In support of the circular economy

'The time is coming when it will no longer make economic sense for 'business as usual' and the circular economy will thrive. Our thinking is in its infancy but we're taking steps now to see what works in practice and to understand the implications of reworking our business model. We are preparing to lead this change by rethinking the way we do business because the reality is, it isn't a choice anymore'.
B&Q Euan Sutherland, CEO of Kingfisher U.K. & Ireland
(Chairman of the B&Q Board)

'The concept of the circular economy tallies completely with our thinking at BT about the importance of providing goods and services sustainably. As a company, we feel intimately involved with these ideas, because digital technology will play a crucial role in providing the information needed to create iterative logistics and restorative systems'.
BT Group Gavin Patterson, Chief Executive BT Retail

'The Circular Economy is a blueprint for a new sustainable economy, one that has innovation and efficiency at its heart and addresses the business challenges presented by continued economic unpredictability, exponential population growth and our escalating demand for the world's natural resources. Pioneering work carried out by the Ellen MacArthur Foundation presents an opportunity to fundamentally rethink how we run our business and challenge all aspects of traditional operating models, from how we use natural resources, to the way we design and manufacture products, through to how we educate and train the next generation. We are delighted to be part of the Ellen MacArthur Foundation and we are committed to exploring how Cisco, our customers, partners and employees can benefit from the principles of the Circular Economy'.
Cisco Chris Dedicoat, President, EMEA

'This is an extremely important time for the energy industry with challenges around sustainability, security and affordability. At National Grid, over the next 9 years, we are looking to recruit in the region of 2,500 engineers and scientists, a mixture of experienced engineers and development programme trainees; all vital to the future of our business. That means we need young people with science, technology, engineering and mathematics skills, with creative minds and a passion to make a difference. The circular economy provides a positive, coherent, innovation challenge through which young people see the relevance and opportunity of these subjects in terms of re-thinking and redesigning their future.'
National Grid Steve Holliday, Chief Executive

'Renault believes that innovation favours progress only if the greatest number stand to benefit from it. Renault believes that the optimisation of existing solutions will not be enough to realise the vision of sustainable mobility for all. The launch of Renault's new game changing fleet of electric vehicles demonstrates that this is possible. A growing population and increasingly volatile resource market will challenge businesses working in a business as usual model. Renault is working in partnership with the Ellen MacArthur Foundation to realise the opportunities of redesigning the future through the vision of a regenerative, circular economy'.
Renault Carlos Tavares, Chief Operating Officer for Renault

Report synopsis

To describe this opportunity to generate rapid and lasting economic benefits and enlist broad support for putting it into full-scale practice, we have structured this report into five chapters, each answering basic questions about the circular economy and the changes it implies:

1

The limits of linear consumption outlines the limits of the current 'take-make-dispose' system and assesses the risks it poses to global economic growth.

2

From linear to circular—Accelerating a proven concept frames the opportunities presented by a circular economy, the origins and early successes of the proven concept of circular business models, and the ways in which they drive value creation.

3

How it works up close—Case examples of circular products demonstrates through detailed case studies the many ways in which companies can benefit from circular business models and the key building blocks needed on a systemic level to shift business in this direction.

4

An economic opportunity worth billions—Charting the new territory maps out what moving towards a circular economy could mean on a macroeconomic level and how circular business models could benefit different market participants.

5

The shift has begun—'Mainstreaming' the circular economy proposes winning strategies for businesses to bring the circular economy into the mainstream and a roadmap for an accelerated transition towards a circular economy.

Executive summary

In the face of sharp volatility increases across the global economy and proliferating signs of resource depletion, the call for a new economic model is getting louder. In the quest for a substantial improvement in resource performance across the economy, businesses have started to explore ways to reuse products or their components and restore more of their precious material, energy and labour inputs. The time is right, many argue, to take this concept of a 'circular economy' one step further, to analyse its promise for businesses and economies, and to prepare the ground for its adoption.

How does the circular economy compare to the race to improve efficiency within today's 'take-make-dispose' economy? What are the benefits of a restorative model to businesses and the economy? How can companies and policy makers carry the concept to its breakthrough at scale? Can some of today's fundamental shifts in technology and consumer behaviour be used to accelerate the transition? To answer these questions for the European Union, our researchers sought to identify success stories of circular business models, to determine what factors enable these success stories, and to glean from these examples a better sense of which sectors and products hold the most potential for circularity, how large this potential might be, and what the broader economic impact could look like. In doing so, we reviewed about a dozen mainstream products reflecting various circular design concepts, undertook economic analysis for key resource-intense business sectors, and interviewed more than 50 experts[1]. What came out clearly resembles a 16th century map more than an exact account of the complete economic benefits. But it is a promising picture, with product case study analyses indicating an annual net material cost savings[2] opportunity of up to USD 380 billion in a transition scenario and of up to USD 630 billion in an advanced scenario, looking only at a subset of EU manufacturing sectors.

1 Unless explicitly stated otherwise, all quotations in this document are from interviews conducted in the period from November 2011 through January 2012 (a list of experts consulted for the analysis and reporting is given in the appendix)

2 Savings described are net of the resources consumed during circular production processes, but they are gross of labour and energy costs. In each case study we examined, energy costs represented an additional source of savings, as will be detailed later in this report. Labour costs represented an additional source of savings for some products but not for others

1. The limits of linear consumption

Throughout its evolution and diversification, our industrial economy has hardly moved beyond one fundamental characteristic established in the early days of industrialisation: a linear model of resource consumption that follows a 'take-make-dispose' pattern. Companies harvest and extract materials, use them to manufacture a product, and sell the product to a consumer—who then discards it when it no longer serves its purpose. Indeed, this is more true now than ever—in terms of volume, some 65 billion tonnes of raw materials entered the economic system in 2010, and this figure is expected to grow to about 82 billion tonnes in 2020 (see Figure 1 in Chapter 1).

Whilst major strides have been made in improving resource efficiency and exploring new forms of energy, less thought has been given to systematically designing out material leakage and disposal. However, any system based on consumption rather than on the restorative use of non-renewable resources entails significant losses of value and negative effects all along the material chain.

Recently, many companies have also begun to notice that this linear system increases their exposure to risks, most notably higher resource prices and supply disruptions. More and more businesses feel squeezed between rising and less predictable prices in resource markets on the one hand and high competition and stagnating demand for certain sectors on the other. The turn of the millennium marked the point when real prices of natural resources began to climb upwards, essentially erasing a century's worth of real price declines (see Figure 4 in Chapter 1). At the same time, price volatility levels for metals, food, and non-food agricultural output in the first decade of the 21st century were higher than in any single decade in the 20th century (see Figure 5 in Chapter 1). If no action is taken, high prices and volatility will likely be here to stay if growth is robust, populations grow and urbanise, and resource extraction costs continue to rise. With three billion new middle-class consumers expected to enter the market by 2030, price signals may not be strong or extensive enough to turn the situation around fast enough to meet this growth requirement. Against this

An annual net material cost savings opportunity of up to USD 380 billion in a transition scenario and of up to USD 630 billion in an advanced scenario, looking only at a subset of EU manufacturing sectors.

backdrop, business leaders are in search of a 'better hedge' and an industrial model that decouples revenues from material input: the 'circular economy'.

2. From linear to circular—Accelerating a proven concept

A circular economy is an industrial system that is restorative or regenerative by intention and design (see Figure 6 in Chapter 2). It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.

Such an economy is based on few simple principles. First, at its core, a circular economy aims to 'design out' waste. Waste does not exist—products are designed and optimised for a cycle of disassembly and reuse. These tight component and product cycles define the circular economy and set it apart from disposal and even recycling where large amounts of embedded energy and labour are lost. Secondly, circularity introduces a strict differentiation between consumable and durable components of a product. Unlike today, consumables in the circular economy are largely made of biological ingredients or 'nutrients' that are at least non-toxic and possibly even beneficial, and can be safely returned to the biosphere—directly or in a cascade of consecutive uses. Durables such as engines or computers, on the other hand, are made of technical nutrients unsuitable for the biosphere, like metals and most plastics. These are designed from the start for reuse. Thirdly, the energy required to fuel this cycle should be renewable by nature, again to decrease resource dependence and increase system resilience (e.g., to oil shocks).

For technical nutrients, the circular economy largely replaces the concept of a consumer with that of a user. This calls for a new contract between businesses and their customers based on product performance. Unlike in today's 'buy-and-consume' economy, durable products are leased, rented, or shared wherever possible. If they are sold, there are incentives or agreements in place to ensure the return and thereafter the reuse of the product or its components and materials at the end of its period of primary use.

These principles all drive four clear-cut sources of value creation that offer arbitrage opportunities in comparison with linear product design and materials usage:

The **'power of the inner circle'** refers to minimising comparative material usage vis-à-vis the linear production system. The tighter the circle, i.e., the less a product has to be changed in reuse, refurbishment and remanufacturing and the faster it returns to use, the higher the potential savings on the shares of material, labour, energy, and capital embedded in the product and on the associated rucksack of externalities (such as greenhouse gas (GHG) emissions, water, toxicity).

The **'power of circling longer'** refers to maximising the number of consecutive cycles (be it reuse, remanufacturing, or recycling) and/or the time in each cycle.

The **'power of cascaded use'** refers to diversifying reuse across the value chain, as when cotton clothing is reused first as second-hand apparel, then crosses to the furniture industry as fibre-fill in upholstery, and the fibre-fill is later reused in stone wool insulation for construction—in each case substituting for an inflow of virgin materials into the economy—before the cotton fibres are safely returned to the biosphere.

The **'power of pure circles'**, finally, lies in the fact that uncontaminated material streams increase collection and redistribution efficiency while maintaining quality, particularly of technical materials, which, in turn, extends product longevity and thus increases material productivity.

These four ways to increase material productivity are not merely one-off effects that will dent resource demand for a short period of time during the initial phase of introduction of these circular setups. Their lasting power lies in changing the run rate of required material intake. They can therefore add up to substantial cumulative advantages over a classical linear business-as-usual case (see Figure 10 in Chapter 2).

Executive summary
Continued

The report provides ample evidence that circularity has started to make inroads on the linear economy and that it has moved beyond the proof of concept—a number of businesses are already thriving on it. Innovative products and contracts designed for the circular economy are already available in a variety of forms—from innovative designs of daily materials and products (e.g., biodegradable food packaging and easy-to-disassemble office printers) to pay-per-use contracts (e.g., for tyres). Demonstrably, these examples have in common that they have focused on optimising the total system performance rather than that of a single component.

3. How it works up close—Case examples of circular products

It is evident that reuse and better design can significantly reduce the material bill and the expense of disposal. But how do these advantages stack up against a production system that has been optimised for throughput? How can the governing principle of 'selling more equals more revenues' be replaced? And how can the choice for circular products, and using rather than consuming, be rendered more attractive for customers?

In order for companies to materialise the savings associated with a circular system by reusing resource inputs to the maximum degree, they need to increase the rate at which their products are collected and subsequently reused and/or their components/materials recuperated. Apart from the automotive industry, few industries currently achieve a collection rate of 25%. When shifting from linear to circular approaches, the rule of thumb for optimisation is: 'the tighter the reverse cycle, the less embedded energy and labour are lost and the more material is preserved'. Today's recycling processes are typically 'loose' or long cycles that reduce material utility to its lowest 'nutrient' level. This is even more true for the incineration of waste. In a circular economy, by contrast, reverse activities in the circular economy will extend across an array of circles for repair and refurbishment of products, and remanufacturing of technical components. Likewise, the reverse chain for biological nutrients returns those back to the biosphere via composting and anaerobic digestion. Furthermore, reverse cycles will not only be confined within an industry but also 'cascaded' across different industries.

We analysed the options for several different categories of resource-intensive products—from fast-moving consumer goods such as food and fashion, longer-lasting products such as phones, washing machines, and light commercial vehicles. We also include single-family houses as an example of a long-life product. We used our circularity model to study products belonging to the 'sweet-spot' segment—the segment with the highest circular economy potential—namely, complex medium-lived products—in full depth. Our analysis showed that use of circular economy approaches would support improvements such as the following:

The cost of remanufacturing mobile phones could be reduced by 50% per device—if the industry made phones easier to take apart, improved the reverse cycle, and offered incentives to return phones.

High-end washing machines would be accessible for most households if they were leased instead of sold—customers would save roughly a third per wash cycle, and the manufacturer would earn roughly a third more in profits. Over a 20-year period, replacing the purchase of five 2,000-cycle machines with leases to one 10,000-cycle machine would also yield almost 180 kg of steel savings and more than 2.5 tonnes of CO_2e savings.

The U.K. could save USD 1.1 billion a year on landfill cost by keeping organic food waste out of landfills—this would also reduce greenhouse gas emissions by 7.4 million tonnes p.a. and could deliver up to 2 GWh worth of electricity and provide much-needed soil restoration and specialty chemicals.

These results and those of the other products studied in detail in this report (light commercial vehicle, smartphone, and textile cascade) confirm that with some adjustments to product design, business model, reverse cycle processes, and/or other enabling factors, the circular system can yield significant material productivity improvements and can be profitable for manufacturers:

Analysis shows that the concept works and is economically viable and scalable for diverse products regardless of length of service life.

Circular design, i.e., improvements in material selection and product design (standardisation/modularisation of components, purer material flows, and design for easier disassembly) are at the heart of a circular economy.

Innovative business models, especially changing from ownership to performance-based payment models, are instrumental in translating products designed for reuse into attractive value propositions.

Core competencies along reverse cycles and cascades involve establishing cost-effective, better-quality collection and treatment systems (either by producers themselves or by third parties).

Enablers to improve cross-cycle and cross-sector performance are factors that support the required changes at a systems level and include higher transparency, alignment of incentives, and the establishment of industry standards for better cross-chain and cross-sector collaboration; access to financing and risk management tools; regulation and infrastructure development; and—last but not least—education, both to increase general awareness and to create the skill base to drive circular innovation.

In summary, our analysis highlights the net benefits a circular economy could bring in terms of reduced material inputs and associated labour and energy costs as well as reduced carbon emissions along the entire supply chain:

Not a niche-only solution. In the past, products associated with a circular model have targeted small niche segments. However, our analysis shows that the concept works and is economically viable and scalable for diverse products regardless of length of service life.

Opportunities now. Despite our conservative assumptions about changes in product and value chain design and consumer adoption, our analysis highlights significant business benefits today—even in a world with entrenched consumer behaviour, imperfect design and material formulations, and far from perfect incentives.

Radical designs win. The more consistently circular design principles were adopted in the R&D phase of the cases we analysed, the higher the economic rewards seem to be. Caterpillar, for example, says it is 'just at the beginning of full circular design—e.g., material science has already and will bring further major progress into the longevity of components.'

Admittedly, this remains a rough chart of the potential for the circular economy. It is our hope, however, that this exercise will provide companies with sufficient confidence to embark on the transformational journey and identify profitable opportunities today—especially piloting circular test cases can often be done with little expansion to the core capabilities and at moderate risk.

4. An economic opportunity worth billions—Charting the new territory

Eliminating waste from the industrial chain by reusing materials to the maximum extent possible promises production cost savings and less resource dependence. However, this report argues that the benefits of a circular economy are not merely operational but strategic, not just for industry but also for customers, and serve as sources of both efficiency and innovation.

How economies win

Economies will benefit from substantial net material savings, mitigation of volatility and supply risks, positive multipliers, potential employment benefits, reduced externalities, and long-term resilience of the economy:

Substantial net material savings. Based on detailed product level modelling, the report estimates that the circular economy represents a net material cost saving opportunity of USD 340 to 380 billion p.a. at EU level for a 'transition scenario' and USD 520 to 630 billion p.a. for an 'advanced scenario', in both cases net of the materials used in reverse-cycle activities (see Figure 18 in Chapter 4). The latter would equate to 19 to 23% of current total input costs[3] or a recurrent 3 to 3.9% of 2010 EU GDP. Benefits in the advanced scenario are highest in the automotive sector (USD 170 to 200 billion p.a.), followed by machinery and equipment

3 Most recent data for sector input costs on EU level come from Eurostat Input/Output tables 2007

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(USD 110 to 130 billion p.a.), and by electrical machinery (USD 75 to 90 billion p.a.). These numbers are indicative as they only cover 'sweet spot' sectors that represent a little less than half of GDP contribution of EU manufacturing sectors. They also assume the addition of only one product cycle with today's technologies. Yet many cycles would be possible and technological innovation could likely lead to rapid improvements and additional cost savings. However, these opportunities are clearly aspirational for now, and companies must make creative and bold moves, break out of the linear system, and ensure that the underlying arbitrage opportunities are robust over time.

Mitigation of price volatility and supply risks. The resulting net material savings would result in a shift down the cost curve for various raw materials. For steel the global net material savings could add up to more than 100 million tonnes of iron ore in 2025 if applied to a sizeable part of the material flows (i.e., in the steel-intensive automotive, machining, and other transport sectors, which account for about 40% of demand). In addition, such a shift would move us away from the steep right-hand side of the cost curve, thus likely reducing demand-driven volatility (see Figure 19 in Chapter 4).

Sectoral shift and possible employment benefits. Creating a 'user-centric economy' especially in the tertiary (services) sector will lead to increased rates of innovation, employment, and capital productivity, all of which are important multipliers.

Reduced externalities. As material and products are the carrier of the embedded externalities, a reduction in volumes will also lead to a reduction in associated externalities—higher than any incremental efficiency improvement in the existing material chain.

Lasting benefits for a more resilient economy. Importantly, any increase in material productivity is likely to have a positive impact on economic development beyond the effects of circularity on specific sectors. Circularity as a 'rethinking device' has proved to be a powerful new frame, capable of sparking creative solutions and stimulating innovation.

The circular approach offers developed economies an avenue to resilient growth, a systemic answer to reducing dependency on resource markets, and a means to reduce exposure to resource price shocks as well as societal and environmental 'external' costs that are not picked up by companies. A circular economy would shift the economic balance away from energy-intensive materials and primary extraction. It would create a new sector dedicated to reverse cycle activities for reuse, refurbishing, remanufacturing, and recycling. At the same time, emerging market economies can benefit from the fact that they are not as 'locked-in' as advanced economies and have the chance to leap-frog straight into establishing circular setups when building up their manufacturing-based sectors. Indeed, many emerging market economies are also more material intensive than typical advanced economies, and therefore could expect even greater relative savings from circular business models. So, the circular economy will have winners, and it is worth exploring the dynamics that the adoption of the circular economy will trigger.

How companies win

Our case studies demonstrate that the principles of the circular economy—if thoughtfully applied—can provide short-term cost benefits today and some striking longer-term strategic opportunities as well as new profit pools in reverse cycle services (collection sorting, funding and financing of new business models).

Importantly, the effects of the circular economy could mitigate a number of strategic challenges companies face today:

Reduced material bills and warranty risks. Through reselling and component recovery, a company can significantly reduce the material bill, even without the effects from yet-to-be-created circular materials and advanced reverse technology. In addition, 'building to last' can also reduce warranty costs.

The principles of the circular economy—if thoughtfully applied—can provide short-term cost benefits today and some striking longer-term strategic opportunities

Improved customer interaction and loyalty. Getting products returned to the manufacturer at the end of the usage cycle requires a new customer relationship: 'consumers' become 'users'. With leasing or 'performance' contracts in place, more customer insights are generated for improved personalisation, customisation, and retention.

Less product complexity and more manageable life cycles. Providing stable, sometimes reusable product kernels or skeletons, and treating other parts of the product as add-ons (such as software, casings, or extension devices), enables companies to master the challenge of ever-shorter product life cycles and to provide highly customised solutions whilst keeping product portfolio complexity low.

How consumers and users win

The benefits of tighter cycles will be shared between companies and customers. And yet the examples in the report indicate that the real customer benefits go beyond the price effect and extend to reduced costs of obsolescence, increased choice, and secondary benefits.

Premature obsolescence is reduced in built-to-last or reusable products. For the customer, this could significantly bring down total ownership costs.

Choice and convenience are increased as producers can tailor duration, type of use, and product components to the specific customer—replacing today's standard purchase with a broader set of contractual options.

Secondary benefits accrue to the customer if products deliver more than their basic function—for example, carpets that act as air filters or packaging as fertiliser. Needless to say, customers will also benefit from the reduction of environmental costs in a circular system.

Whilst the transition to a circular economy will bring dislocations, higher resource and materials productivity should have a stabilising effect, creating some 'breathing room' as the world deals with the strains of expanding and ageing societies.

5. The shift has begun—'Mainstreaming' the circular economy

Our economy is currently locked into a system where everything from production economics and contracts to regulation and mindsets favours the linear model of production and consumption. However, this lock-in is weakening under the pressure of several powerful disruptive trends: First, **resource scarcity and tighter environmental standards** are here to stay. Their effect will be to reward circular businesses over 'take-make-dispose' businesses. As National Grid explains: 'we are now analysing our supply chains systematically [for circularity potential]. The potential is bigger than we initially thought'.

Second, **information technology** is now so advanced that it can be used to trace material through the supply chain, identify products and material fractions, and track product status during use. Furthermore, social media platforms exist that can be used to mobilise millions of customers around new products and services instantaneously.

Third, we are in the midst of a **pervasive shift in consumer behaviour.** A new generation of customers seem prepared to prefer access over ownership. This can be seen in the increase of shared cars,[4] machinery, and even articles of daily use. In a related vein, social networks have increased the levels of transparency and consumers' ability to advocate responsible products and business practices.

Circular business design is now poised to move from the sidelines and into the mainstream. The mushrooming of new and more circular business propositions—from biodegradable textiles to utility computing—confirms that momentum.

And yet, the obstacles remain daunting. They range from current product design, to cultural resistance, to 'subsidised' commodity and energy prices. Some of these barriers may fade on their own, with time. Others could require specific new frameworks—in terms of corporate governance, cross-industry collaboration, technology, or regulation.

4 Organised car sharing has been growing from fewer than 50,000 members of car-sharing programs globally in the mid-1990s, to around 500,000 in the late 2000s. According to Frost & Sullivan, this number is likely to increase another 10-fold between 2009 and 2016

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To push circularity past its tipping point and capture the larger prize projected for 2025, the Ellen MacArthur Foundation and its partners intend to lay further groundwork and work towards the removal of some significant obstacles. Here is a roadmap for that revolution:

The next five years will be the **pioneering phase.** We expect that industry pioneers will start building competitive advantage in various ways: they will build core competencies in circular product design, drive business model innovation, create the capacities for the reverse cycle, and use the brand and volume strength of leading corporations to gain market share. With these prerequisites in place, the benefits associated with our transition scenario seem within reach—material cost savings in the 'sweet spot' sectors of 12 to 14% p.a.

Towards 2025, there is a chance for circularity to go mainstream, and for savings to move beyond the 20% mark, as described in the advanced scenario. However, more transformational change is needed from the corporate sector and from government given today's taxation, regulatory, and business climate. The **mainstreaming phase** will involve organising reverse-cycle markets, rethinking taxation, igniting innovation and entrepreneurship, stepping up education, and issuing a more suitable set of environmental guidelines and rules—especially with regards to properly accounting for externalities.

Moving manufacturing away from wasteful linear material consumption patterns could prove to be a major innovation engine, much as the renewable energy sector is today.

Such a transition offers new prospects to economies in search of sources of growth and employment.At the same time, it is a source of resilience and stability in a more volatile world. Its inception will likely follow a 'creative destruction' pattern and create winners and losers. The time to act is now.

As our resource consumption and dependence continue to rise and our growth threatens to negate our production efficiency efforts, governments and companies have started looking at the circular model not only as a hedge against resource scarcity but as an engine for innovation and growth. This report suggests that this opportunity is real and represents an attractive new territory for pioneering enterprises and institutions. This report is, however, just the start of a mobilisation process—we intend to go deeper into different products and sectors, assess the business opportunity in more detail, identify roadblocks and provide the tools to overcome them, and understand the macroeconomic impacts in more depth. The Ellen MacArthur Foundation and its partners are committed to identifying, convening, and motivating the pioneers of the circular economy. The Foundation provides the fact base and case study repository, shares best practices, and excites and educates the next generation through the opportunities this redesign revolution creates. In this way, it helps to bring down the barriers and create the leadership and momentum that the bold vision of the circular economy deserves.

The limits of linear consumption

1

Outlines the limits of the current 'take-make-dispose' system and assesses the risks it poses to global economic growth.

1. The limits of linear consumption

Throughout its evolution and diversification, our industrial economy has never moved beyond one fundamental characteristic established in the early days of industrialisation: a linear model of resource consumption that follows a 'take-make-dispose' pattern. Companies extract materials, apply energy and labour to manufacture a product, and sell it to an end consumer—who then discards it when it no longer serves its purpose. While great strides have been made in improving resource efficiency, any system based on consumption rather than on the restorative use of resources entails significant losses all along the value chain.

Recently, many companies have also begun to notice that this linear system increases their exposure to risks, most notably higher resource prices. More and more businesses feel squeezed between rising and less predictable prices in resource markets on the one hand and stagnating demand in many consumer markets on the other. The start of the new millennium marks the turning point when real prices of natural resources began to surge upwards, essentially erasing a century's worth of real price declines. At the same time, price volatility levels for metals, food, and non-food agricultural output in the first decade of the 21st century were higher than in any single decade in the 20th century. Prices and volatility are likely to remain high as populations grow and urbanise, resource extraction moves to harder-to-reach locations, and the environmental costs associated with the depletion of natural capital increase.

Against this backdrop, the search for an industrial model that can further decouple sales revenues from material input has increased interest in concepts associated with the 'circular economy'. Though still a theoretical construct, the term 'circular economy' denotes an industrial economy that is restorative by intention and design. In a circular economy, products are designed for ease of reuse, disassembly and refurbishment, or recycling, with the understanding that it is the reuse of vast amounts of material reclaimed from end-of-life products, rather than the extraction of resources, that is the foundation of economic growth. With the adoption of a circular economy, unlimited resources like labour take on a more central role in economic processes, and resources that are limited by natural supply play more of a supporting role. This concept holds considerable promise, as has already been verified in a number of industries, of being able to counter-act the imbalances currently building up between the supply of and demand for natural resources.

More efficiency remains desirable, but to address the magnitude of the resource crunch now approaching, minimising inputs must be joined by innovating the way we work with the output. Making the leap from consuming and discarding products to using and reusing them to the maximum extent possible, in closer alignment with the patterns of living systems, is vital to ensure that continuing growth generates greater prosperity.

Since farming began in the Fertile Crescent around 10,000 years ago, the world's population has increased nearly 15,000-fold, from an estimated total of 4 million[5] (less than half the population of Greater London today) to pass the 7 billion mark in October 2011—and it is projected to grow to 9 billion by 2050. While about two billion people continue to subsist in basic agrarian conditions or worse, three billion are expected to join the ranks of middle-class consumers by 2030. Their new prosperity will trigger a surge of demand both larger and in a shorter time period than the world has ever experienced. Even the most conservative projections for global economic growth over the next decade suggest that demand for oil, coal, iron ore, and other natural resources will rise by at least a third, with about 90% of that increase coming from growth in emerging markets.[6]

The current 'take-make-dispose' model entails significant resource losses

Through most of the past century, declining real resource prices have supported economic growth in advanced economies.[7] The low level of resource prices, relative to labour costs, has also created the current wasteful system of resource use. Reusing materials has not been a major economic priority, given the ease of obtaining new

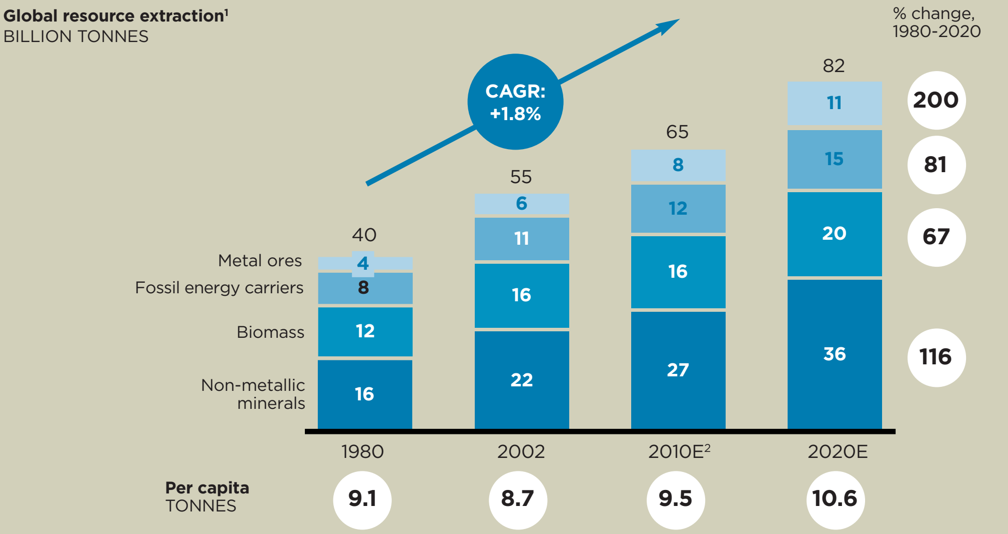
5 McEvedy, C., and R. Jones (1978), Atlas of World Population History, 368 pp., Penguin, London

6 McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs; November 2011

7 The low and steadily falling level of resource prices, in real terms, over the 20th century—and its positive implications for economic growth—are discussed in depth in the McKinsey Global Institute's November 2011 report Resource Revolution, cited above

FIGURE 1

Global resource extraction is expected to grow to 82 billion tonnes in 2020



1 Resource used: amount of extracted resources that enters the economic system for further processing or direct consumption. All materials used are transformed within the economic system, incl. material used to generate energy and other material used in the production process
2 Forecasted from 2002 OECD figures and OECD extraction scenario for 2020

SOURCE: OECD; Behrens (2007); WMM Global Insight; Ellen MacArthur Foundation circular economy team

input materials and cheaply disposing of refuse. In fact, the biggest economic efficiency gains have resulted from using more resources, especially energy, to reduce labour costs. The system has had difficulties in correcting itself as long as the fiscal regimes and accounting rules that govern it allowed for a broad range of indirect costs to remain unaccounted for—the so-called 'externalities'. Further inertia on the part of the market stems from lock-in effects, for example due to the lengthy and costly approval periods faced by some products such as pharmaceuticals and fertilisers.

We characterise the resulting system as a 'take-make-dispose' or 'linear' model. The premise of this model is simple: companies extract materials, apply energy to them to manufacture a product, and sell the product to an end consumer, who then discards it when it no longer works or no longer serves the user's purpose. The linear production model incurs unnecessary resource losses in several ways:

Waste in the production chain. In the production of goods, significant volumes of materials are commonly lost in the chain between mining and final manufacturing. For instance, the Sustainable Europe Research Institute (SERI) estimates that, each year, the manufacturing of products in OECD countries consumes over 21 billion tonnes of materials that aren't physically incorporated into the products themselves (i.e., materials that never enter the economic system—such as overburden and parting materials from mining, by-catch from fishing, wood and agricultural harvesting losses, as well as soil excavation and dredged materials from construction activities).[8]

Food markets provide a snapshot of wastage along the value chain. Losses of materials occur at several different steps in the production of food: losses in the field due to pests or pathogens, losses during agricultural production due to poor efficiency, spills or leakages during transport (exacerbated by ever-longer global supply chains), losses during storage and at the retailer's due to food surpassing its sell-by date or being stored in the wrong conditions, and products simply going unused by end consumers. Along the entire food supply chain, these losses globally add up to an estimated one-third of food produced for human consumption every year.[9]

End-of-life waste. For most materials, rates of conventional recovery after the end of their (first) functional life are quite low compared with primary manufacturing rates. In terms of volume, some 65 billion tonnes of raw materials entered the global economic system in 2010—a figure expected to grow to about 82 billion tonnes in 2020 (Figure 1). In Europe, 2.7 billion tonnes of waste was generated in 2010, but only about 40% of that was reused, recycled, or composted and digested (Figure 2). Looking at individual waste streams, an even starker picture emerges: current recycling rates are significant for only a handful of waste types, mostly those that occur in large, fairly homogeneous volumes. A recent UNEP report,[10] for example, notes that only around

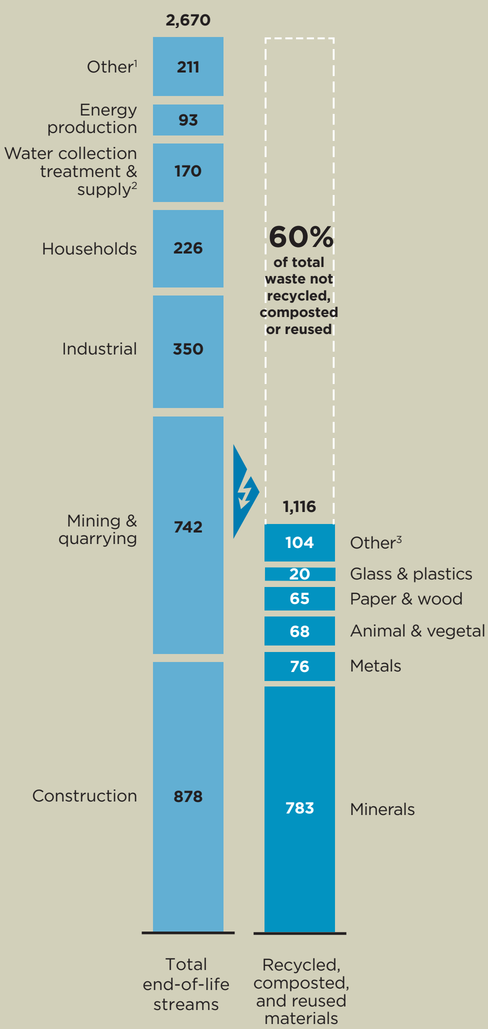
8 Materialsflows.net

9 J. Gustavsson, C. Cederberg, U. Sonesson, R. van Otterdijk, A. Meybeck. Global food losses and food waste – Extent, causes and prevention. Food And Agriculture Organization Of The United Nations, Rome, 2011

10 UNEP International Resource Panel Recycling Rates of Metals – a status report. 2011

1. The limits of linear consumption
Continued

FIGURE 2
We are still losing enormous tonnages of material
Million tonnes, EU27, 2010E



1 Includes services and agriculture, forestry & fishing
2 Also includes sewerage and other waste management activities
3 Includes used oils, rubber, textiles, household waste, chemical waste, and other non-specified

SOURCE: Eurostat waste statistics (2011)

one-third of the 60 metals it studied showed a global end-of-life recycling rate of 25% or more. Taking a closer look at various ferrous and non-ferrous metals reveals that even for metals that already have high recycling rates, significant value is lost—ranging from annual losses of USD 52 billion for copper and USD 34 billion for gold, to USD 15 billion for aluminium and USD 7 billion for silver.[11 12]

Losses are also apparent at the level of specific industries. Rubble produced during the construction and demolition of buildings, which accounts for 26% of the total non-industrial solid waste produced in the United States, includes many recyclable materials from steel to wood to concrete. Only 20 to 30% of all construction and demolition waste is ultimately recycled or reused, often because buildings are designed and built in a way that is not conducive to breaking down parts into recyclable let alone reusable components (Figure 3).[13] The result is a significant loss of valuable materials for the system.

Energy use. In the linear system, disposal of a product in landfill means that all its residual energy is lost. The incineration or recycling of discarded products recoups a small share of this energy, whereas reuse saves significantly more energy. The use of energy resources in a linear production model is typically most intensive in the upstream parts of the supply chain—i.e., the steps involved in extracting materials from the earth and converting them into a commercially usable form. In the production of semi-finished aluminium products ('semis'), for instance, the processes of refining, smelting, and casting bauxite into semi-finished aluminium account for 80% of the energy consumed (and 67% of the total costs incurred).[14] Because much of this energy can be saved with a system that relies less on upstream production, i.e., does not use new materials as inputs each time a product is made, the aluminium industry and its customers have been quite relentless in pursuing high recycling rates (according to UNEP, end-of-life recycling rates for aluminium range from 43 to 70%, while those for other major non-ferrous metals are lower—e.g., copper 43 to 53%, zinc 19 to 52%, magnesium 39%).[15] This has not been the case for most other metals, although it is particularly relevant in an economic system that is largely dependent on fossil fuels for the provision of its energy, as these cannot be replaced within a reasonable time scale and come with a greenhouse gas footprint. While the consumption of energy for biological inputs is spread fairly evenly along the value chain, here, too, total consumption is significant—in the U.S., for example, it is 17% of all energy demand[16] —and the reduction of post-consumer food waste

11 U.S. Geological Survey Minerals Information Database

12 Losses are calculated based on expected recovered volume of 2010 metal production, assuming today's recycling rates remaining constant until end-of-life of all product applications. The difference between recovered volume and hypothetically recoverable volumes under complete recycling, multiplied with today's market prices for secondary materials, gives monetary loss

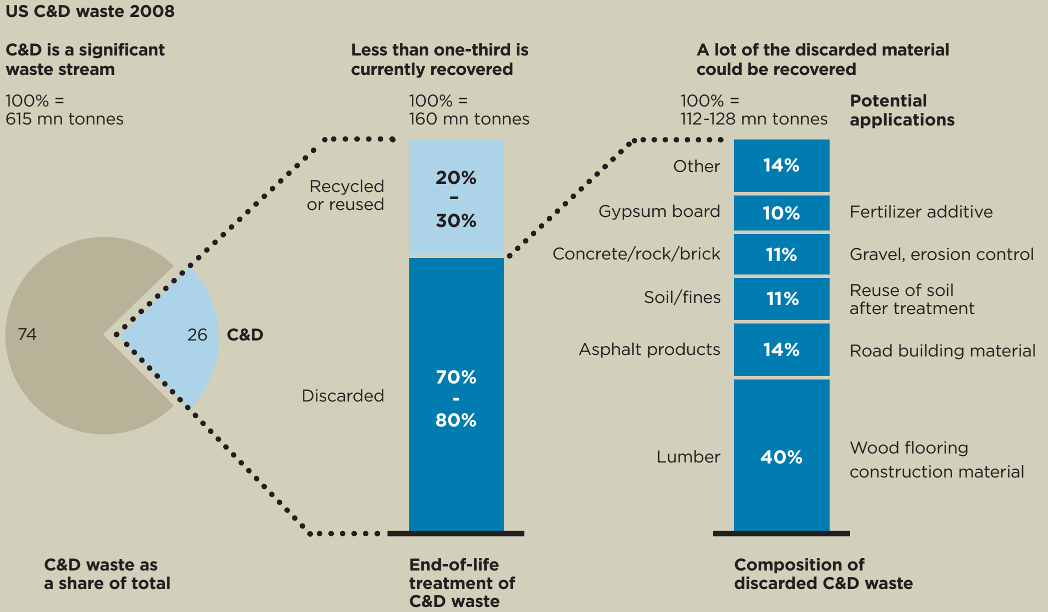
13 U.S. EPA, Buildings and their Impact on the Environment: A Statistical Summary; revised April 22, 2009

14 JFK database; WBMS; EAA; IAI; NFID model v4.30; McKinsey analysis

15 UNEP International Resource Panel, Recycling Rates of Metals – a status report. 2011

16 McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs; November 2011

FIGURE 3
Construction and demolition (C&D): A noteworthy opportunity



SOURCE: Buildings and their Impact on the Environment: A Statistical Summary; revised April 22, 2009 – EPA; Journal of Environmental Engineering; Ellen MacArthur Foundation circular economy team

could thus offer tremendous energy savings. The reduced energy intensity of the circular model results in a reduction of threshold energy demand and further enables a shift to renewable energy—a virtuous cycle.

Erosion of ecosystem services. At least as troubling as climate change, and far less well understood, is the erosion over the past two centuries of 'ecosystem services', that is those benefits derived from ecosystems that support and enhance human wellbeing, such as forests (which, as an essential counterpart of atmospheric, soil, and hydrological systems, absorb carbon dioxide and emit oxygen, add to soil carbon, and regulate water tables—and deliver a host of other benefits). The Millennium Ecosystem Assessment examined 24 ecosystems services, from direct services such as food provision to more indirect services such as ecological control of pests and diseases, and found that 15 of the 24 are being degraded or used unsustainably. In other words, humanity now consumes more than the productivity of Earth's ecosystems can provide sustainably, and is thus reducing the Earth's natural capital, not just living off of its productivity.[17 18] As an example of the potential cost associated with this trend, a recent report, The Economics of Ecosystems and Biodiversity, suggests that ecosystem services lost to deforestation in China alone cost the global economy some USD 12 billion annually over the period from 1950 to 1998. These losses accrue across several dimensions, including the costs of climate and water regulation, the depletion of timber and fuel supplies, losses in agricultural productivity, and the costs of lost nutrient cycling, soil conservation, and flood prevention.[19]

The current model creates imbalances that weigh on economic growth

The troubles inherent in a system that does not maximise the benefits of energy and natural resource usage have become evident both in the high level of real commodity prices, and in their volatility.

Since 2000, the prices of natural resources have risen dramatically, erasing a century's worth of real price declines. In McKinsey's Commodity Price Index for 2011, the arithmetic average of prices in four commodity sub-indices (food, non-food agricultural items, metals, and energy) stood at a higher level than at any time in the past century (Figure 4).[20] Higher prices for commodities, most notably oil and food, are in the headlines—from the record-breaking USD 147/barrel price for West Texas Intermediate crude oil in 2008 to the 107% rise in wheat prices from June 2010 to January 2011, setting off unrest in several emerging market economies.[21 22] Similarly dramatic price increases have hit other commodities, from base metals to precious metals and specialty materials like rare earth oxides. Even in the absence of specific price spikes, sustained higher resource costs

17 Ruth DeFries, Stefano Pagiola et al, Millennium Ecosystem Assessment, Current State & Trends Assessment, 2005

18 Will Steffen, Åsa Persson et al, The Anthropocene: From Global Change to Planetary Stewardship, 2011

19 TEEB for Business, The Economics of Ecology and Biodiversity, 2010

20 Sources: Grilli and Yang; Pfaffenzeller; World Bank; International Monetary Fund; Organisation for Economic Cooperation and Development statistics; UN Food and Agriculture Organization; UN Comtrade; McKinsey analysis

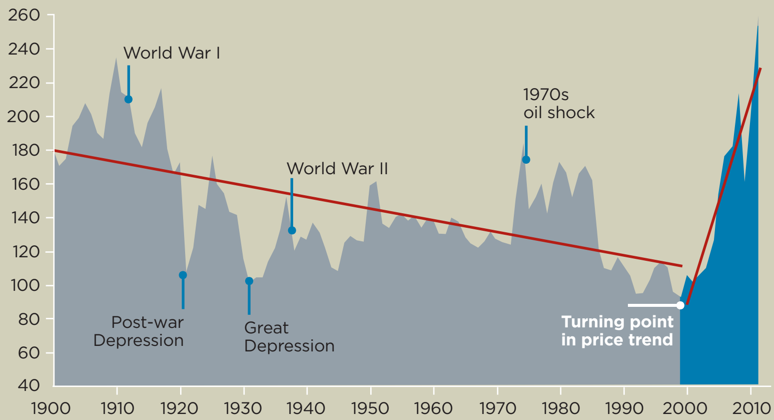
21 Chicago Mercantile Exchange (http://www.cmegroup.com/company/history/magazine/vol7-issue2/epicenterof-energy.html)

22 IndexMundi (http://www.indexmundi.com/commodities/?commodity=wheat&months=60)

1. The limits of linear consumption
Continued

FIGURE 4
Sharp price increases in commodities since 2000 have erased all the real price declines of the 20th century

McKinsey Commodity Price Index (years 1999-2001 = 100)[1]



1 Based on arithmetic average of 4 commodity sub-indices: food, non-food agricultural items, metals, and energy; 2011 prices based on average of first eight months of 2011.

SOURCE: Grilli and Yang; Pfaffenzeller; World Bank; International Monetary Fund; Organisation for Economic Co-operation and Development statistics; UN Food and Agriculture Organization; UN Comtrade; Ellen MacArthur Foundation circular economy team

could certainly dampen the prospects for an already fragile global economy, and are not going unnoticed by companies.

Also troubling, from a business standpoint, is the recent jump in the volatility of resource prices. For metals, food, and non-food agricultural items, volatility levels in the first decade of the 21st century were higher than in any decade in the 20th century (Figure 5).[23]

Several factors have driven commodity price volatility over the past decade. First, increased demand for many metals has pushed prices to the far right end of their respective cost curves—where the cost of producing an additional unit of output is relatively high. This results in a situation where small shifts in demand can lead to disproportionately large price swings. Simultaneously, the exhaustion of easy-to-access reserves has increased the technological requirements for extracting many commodities—from oil and gas to zinc and gold—making resource access more vulnerable to malfunctions and hence disruptions in the supply chain. Weather patterns and political shocks, too, have continually jarred supply dynamics. And finally, innovation in financial markets (including the development and proliferation of exchange-traded funds) has given new investors access to commodity markets, creating the potential for 'fad' investments to exacerbate near-term price swings.

Together, high and volatile commodity prices dampen the growth of global businesses—and ultimately economic growth. These effects manifest themselves in two main ways: input cost spikes and increasing hedging costs. As commodity prices have risen, companies have reported a hit on profits due to sharp increases in input costs. PepsiCo, for instance, announced in February 2011 that it expected input costs for the fiscal year to rise by USD 1.4 to 1.6 billion, or between 8 and 9.5% of total input costs, due to commodity price increases.[24] PepsiCo also said that it didn't plan to fully offset these losses through price-hikes—highlighting another, parallel trend, in which firms face a 'profit squeeze' because competition prevents them from offsetting input price increases by raising their sales price. Tata Steel offers another recent case in point: the purchase price of input materials for steelmaking jumped, but the market price for steel did not rise enough to offset Tata's suddenly higher costs, leading to lost margins for the company.[25] Some firms that rely heavily on commodities as raw inputs minimise their exposure to future price-swings via hedging contracts—at a cost. The total cost of hedging varies significantly depending on a company's credit rating and the expected volatility of markets, but in the current market environment, a firm lacking a first-rate credit history could well spend 10% of the total amount it hedges on financial service fees.[26] These fees represent not only a direct cost but also an opportunity cost—in less volatile markets, money is more likely to be spent on business projects, research, and innovation, potentially leading to growth.

Current imbalances are likely to get worse before they get better

Several factors indicate that resource scarcity, price squeezes, and volatility will continue or increase. Here we outline some of the more prominent challenges of meeting future resource needs:

23 Annual price volatility calculated as the standard deviation of McKinsey commodity subindices divided by the average of the subindex over the time frame; Source: McKinsey Global Institute

24 Jonathan Birchall, 'Pepsi faces steep input price inflation', Financial Times, 10 February 2011

25 'Tata Steel Q2 net profit plunges 89%', Economic Times, 11 November 2011

26 Chana Schoenberger, "Exposed!" The Wall Street Journal, 2 March,, 2011

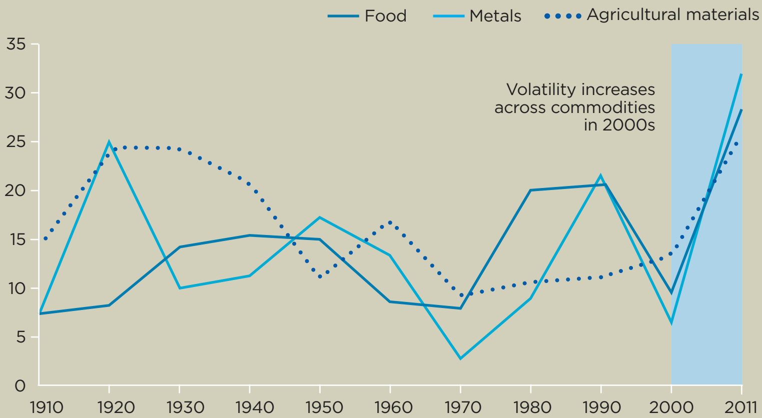
27 Per-capita GDP, measured in 1990 international dollars, PPP and inflation weighted; Source: Angus Maddison; University of Groningen

28 McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs; November 2011

FIGURE 5

Price volatility has risen above long-term trends in recent decades

Price volatility[1], in %, 10-year average ending at start of year cited[2]



1 Calculated as the standard deviation of the commodity sub-index divided by the average of the sub-index over the time frame
2 2000-2011: 11-year average

SOURCE: Grilli and Yang; Pfaffenzeller; World Bank; International Monetary Fund; Organisation for Economic Co-operation and Development statistics; UN Food and Agriculture Organization; UN Comtrade; Ellen MacArthur Foundation circular economy team

Demographic trends. The world faces a unique demographic challenge over the coming decades—though the economic aspects of demographics may prove more difficult to manage than the population aspects. China and India, the two largest countries by population, are each poised to undergo a significant economic transition in coming decades. Looking at the recent past gives a sense of both the scope and the speed of the shift. China, starting in 1982, took only 12 years to double its per-capita GDP from USD 1,300–2,600, and India, starting in 1989, took only 16 years to achieve the same doubling.[27] By comparison, it took the United Kingdom 154 years to make the same transition. Every bit as striking is the sheer number of people in China's and India's populations entering these periods of economic growth—which implies that a breathtaking number of new middle-class consumers could be entering the global economy if the two countries continue their current growth patterns. McKinsey anticipates the emergence of three billion new middle-class consumers by 2030, led by economic growth in these two countries and other rapidly growing—and significantly sized—emerging market economies.[28] This mass of new spenders will have significant impact on resource demand, a prospect that underlines the potential value of introducing circular economy principles into business models sooner rather than later. The baseline UN forecast for global population growth projects the global population will stabilise at around 10 billion by 2100.[29] All the same, important demographic shifts within the global population could ultimately prove more important than the size of the population itself, especially the three billion new individuals entering the consuming middle class by 2030.[30]

Infrastructure needs. Besides more infrastructure for a larger population, the world will also need to expand its infrastructure to get at harder-to-access resources. Newly discovered reserves do exist, but tapping them will require heavy investment in infrastructure and new technology. McKinsey estimates that (all else being equal) meeting future demands for steel, water, agricultural products, and energy would require a total investment of around USD 3 trillion per year[31] —an amount roughly 50% higher than current investment levels. Should this investment fail to materialise, the result could be continued supply constraints. This threat is particularly pressing for agriculture in advanced economies, many of which are much closer to the technological limit and already producing near their maximum potential yields.[32]

Political risks. Recent history shows the impact political events can have on commodity supply. There are numerous historical instances in which political events have triggered commodity price spikes: the 1972 Arab oil embargo is one example; another is the export declines following the 1978 Iranian revolution; a third is the price shocks following Iraq's invasion of Kuwait in 1990.[33] Some commodities are particularly vulnerable: nearly half the new projects to develop copper reserves, for instance, are in countries with high political risk.[34] Perhaps more shockingly, roughly 80% of all available arable land on earth lies in areas afflicted by political or infrastructural issues. Some 37% of the world's proven oil reserves, and 19% of proven gas reserves, are also in countries with a high level of political risk. Political decisions also drive cartels, subsidies, and trade barriers, all of which can trigger or worsen resource scarcity and push up prices and volatility levels

29 The most reliable and commonly cited models for global population growth are those of the United Nations. The UN's estimates vary significantly based on the fertility rate used as an input, but all of their core scenarios involve fertility rates significantly below the current global rate

30 United Nations Population Division: World Population Prospects: 2010 Revision, 2010; and McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs; November 2011"

31 McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs; November 2011

32 Based on yield achievement of wheat, rice, maize, and soybean; maximum attainable yield provided by International Institute for Applied Systems Analysis and benchmarked by region based on climate and technology. Data from Food and Agriculture Organization and International Institute for Applied Systems Analysis

33 'Oil markets and Arab unrest: The Price of Fear', The Economist, March 3, 2011

34 Political risk as per the Economist Intelligence Unit's Political Instability Index. Countries scoring more than 5.0 on 'underlying vulnerability' are classified as 'low political stability'

1. The limits of linear consumption
Continued

Globalised markets. The rapid integration of financial markets and the increasing ease of transporting resources globally mean that regional price shocks can quickly become global. There are many examples in recent history, from the impact that Hurricane Ike in the Gulf of Mexico had on energy markets, to the air travel chaos caused by the eruption of the Eyjafjallajökull in Iceland, to the supply chain disruptions ensuing from the Fukushima disaster in Japan. This trend is likely to continue and, in all likelihood, to become more acute as emerging markets integrate more thoroughly into global value chains and financial systems.

Climate. Some resource industries could face disruption from variations in regional climates over time, particularly water and agriculture. The U.S. Environmental Protection Agency suggests that changes in climate could affect snow cover, stream flow, and glacial patterns—and hence fresh water supply, erosion patterns, irrigation needs, and flood management requirements, and thus the overall supply of agricultural products.[35] Supply constraints and uncertainty would likely drive up prices and volatility. McKinsey research suggests that by 2030, the disparity between global water demand and water supply could reach 40%, driven in large part by increased demand for energy production, which is highly water-intensive.[36]

Taken together, these dynamics present a major challenge for the current 'take-make-dispose' system. While this system, too, will respond to price signals, these signals are incomplete and distorted. We therefore believe that under a business-as-usual scenario the market will not overcome the lock-in effect of existing production economics, regulations, and mindsets and will therefore not address the large and continued imbalances described here quickly and extensively enough to be able to keep meeting future demand. If it was declining resource prices that fuelled much of the economic growth of the past century, upward price shifts could, if not stall, then severely hamper further growth in the decades to come.

It is true that a few individual companies have already started taking the initiative to counter the negative effects of a linear approach. The set of benefits that can be captured by an individual company on its own, however, is bounded, and system limitations will need to be addressed in order to let markets react fully to the pricing signals described. A good example of such system-enhancing steps is the levying of landfill taxes in a growing number of countries, as this provides a more level playing field for waste treatment and product recovery methods that aim to preserve resources. A further step might then be to render some of the environmental and social effects of our resource-based systems more visible so as to let them steer the market.

In this report, we argue for a specific type of productivity—a more 'circular' business model in which many more products are reused, refurbished, and redistributed than today. More components and materials could be remanufactured and ultimately recycled. And more food and other organic waste could loop through value-extracting processes such as biochemical extraction and anaerobic digestion. Our preliminary research shows that moving in the direction of such a model could lead to significant economic benefits for specific industries. It could more broadly help mitigate aspects of the current system that put pressure on resource supply, commodity prices, and volatility. It could also restore the natural capital that is essential for the continual provision of food, feed, and fibre.

35 'Climate Change Indicators: Snow and Ice', from: Climate Change Indicators Report, U.S. Environmental Protection Agency, 2010, p. 54

36 McKinsey and Company: Transforming the Water Economy – Seven Ways to Ensure Resources for Growth; January 2011

From linear to circular
Accelerating a proven concept

2

Frames the opportunities presented by a circular economy, the origins and early successes of the proven concept of circular business models, and the ways in which they drive value creation.

2. From linear to circular
Accelerating a proven concept

The linear 'take-make-dispose' model relies on large quantities of easily accessible resources and energy, and as such is increasingly unfit for the reality in which it operates. Working towards efficiency alone—a reduction of resources and fossil energy consumed per unit of manufacturing output—will not alter the finite nature of their stocks but can only delay the inevitable. A change of the entire operating system seems necessary.

The circular economy perspective and principles

The circular economy refers to an industrial economy that is *restorative* by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design. The term goes beyond the mechanics of production and consumption of goods and services in the areas that it seeks to redefine (examples include rebuilding capital, including social and natural, and the shift from consumer to user). The concept of the circular economy is grounded in the study of non-linear systems, particularly living ones. A major consequence of taking insights from living systems is the notion of optimising systems rather than components, which can also be referred to as 'design to fit'. It involves a careful management of materials flows, which, in the circular economy, are of two types as described by McDonough and Braungart: biological nutrients, designed to re-enter the biosphere safely and build natural capital, and technical nutrients, which are designed to circulate at high quality without entering the biosphere.[37]

As a result, the circular economy draws a sharp distinction between the *consumption* and *use* of materials: circular economy advocates the need for a 'functional service' model in which manufacturers or retailers increasingly retain the ownership of their products and, where possible, act as service providers—selling the use of products, not their one-way consumption. This shift has direct implications for the development of efficient and effective take-back systems and the proliferation of product- and business-model design practices that generate more durable products, facilitate disassembly and refurbishment, and consider product/service shifts, where appropriate. As circular economy thinker Walter Stahel explains, 'The linear model turned services into products that can be sold, but this throughput approach is a wasteful one. [...] In the past, reuse and service-life extension were often strategies in situations of scarcity or poverty and led to products of inferior quality. Today, they are signs of good resource husbandry and smart management'.[38]

The circular economy is based on a few simple principles

Design out waste. Waste does not exist when the biological and technical components (or 'nutrients') of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and refurbishment. The biological nutrients are non-toxic and can be simply composted. Technical nutrients—polymers, alloys, and other man-made materials are designed to be used again with minimal energy and highest quality retention (whereas recycling as commonly understood results in a reduction in quality and feeds back into the process as a crude feedstock).

Build resilience through diversity. Modularity, versatility, and adaptivity are prized features that need to be prioritised in an uncertain and fast-evolving world. Diverse systems with many connections and scales are more resilient in the face of external shocks than systems built simply for efficiency—throughput maximisation driven to the extreme results in fragility.

Michael Braungart confirms, 'Natural systems support resilient abundance by adapting to their environments with an infinite mix of diversity, uniformity and complexity. The industrial revolution and globalisation focused on uniformity so our systems are often unstable. To fix that we can manufacture products with the same flair for resilience by using successful natural systems as models'.

Rely on energy from renewable sources. Systems should ultimately aim to run on renewable sources. As Vestas, the wind energy company, puts it: 'Any circular story should start by looking into the energy

37 William McDonough and Michael Braungart, Cradle to Cradle: remaking the way we make things, New York: North Point Press, 2002

38 Unless explicitly stated otherwise, all quotations in this document are from interviews conducted in the period from November 2011 through January 2012 (A list of experts consulted for the analysis and reporting is given in the appendix)

'Rather than using eco-efficiency to try and minimise material flows, eco-effectiveness transforms products and related material flows to support a workable relationship between ecological systems and economic growth. Instead of reducing or delaying the cradle-to-grave flow of materials, eco-effectiveness creates metabolisms where materials are used over and over again at a high level of quality.' Michael Braungart

Efficiency vs. effectiveness—a key distinction

Eco-efficiency begins with the assumption of a one-way, linear flow of materials through industrial systems: raw materials are extracted from the environment, transformed into products, and eventually disposed of. In this system, eco-efficient techniques seek only to minimise the volume, velocity, and toxicity of the material flow system, but are incapable of altering its linear progression. Some materials are recycled, but often as an end-of-pipe solution, since these materials are not designed to be recycled. Instead of true recycling, this process is actually downcycling, a downgrade in material quality, which limits usability and maintains the linear, cradle-to-grave dynamic of the material flow system.

In contrast to this approach of minimisation and dematerialisation, the concept of eco-effectiveness proposes the transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth. The goal is not to minimise the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources and accumulate intelligence over time (upcycling). This inherently generates a synergistic relationship between ecological and economic systems, a positive recoupling of the relationship between economy and ecology.

involved in the production process'. Walter Stahel has argued that human labour should fall in that same category: 'Shifting taxation from labour to energy and material consumption would fast-track adoption of more circular business models; it would also make sure that we are putting the efficiency pressure on the true bottleneck of our resource consuming society/economy (there is no shortage of labour and (renewable) energy in the long term).'

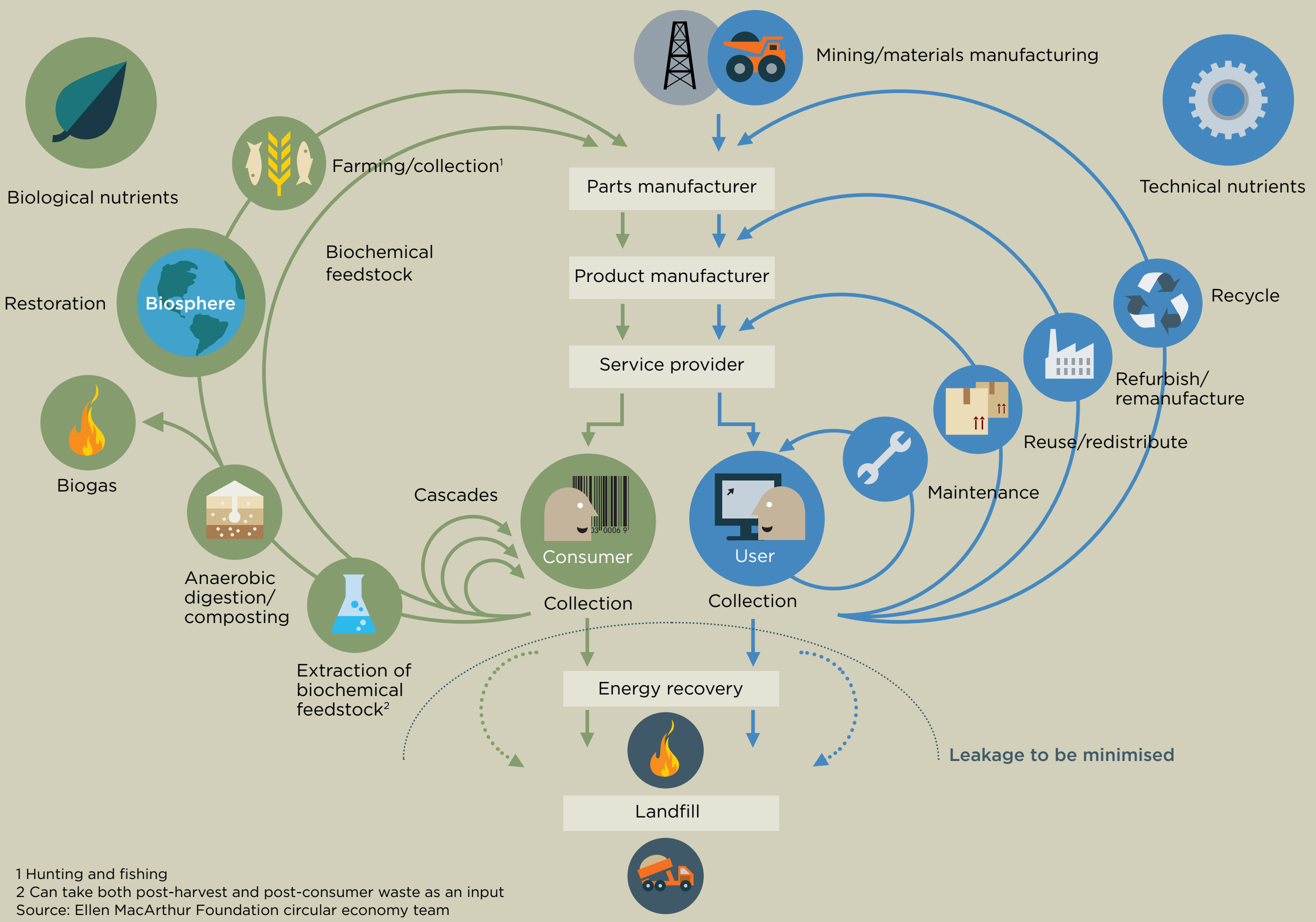
Think in 'systems'. The ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts, is crucial. Elements are considered in their relationship with their infrastructure, environment, and social contexts. Whilst a machine is also a system, it is bounded and assumed to be deterministic. Systems thinking usually refers to non-linear systems (feedback-rich systems). In such systems, the combination of imprecise starting conditions plus feedback leads to multiple, often surprising consequences and to outcomes that are not necessarily proportional to the input. Applying these insights to engineering and business challenges, Chris Allen, CEO of Biomimicry 3.8, explains: 'In our work with our clients, we will frame the problems we aim to solve from a systems integration perspective, and always in context—since in nature nothing grows out of context'. Systems thinking emphasises flow and connection over time and has the potential to encompass regenerative conditions rather than needing to limit its focus to one or more parts and the short term.

Waste is food. On the biological nutrient side, the ability to reintroduce products and materials back into the biosphere through non-toxic, restorative loops is at the heart of the idea. On the technical nutrient side, improvements in quality are also possible; this is called upcycling.

The drive to shift the material composition of *consumables* from technical towards biological nutrients and to have those cascade through different applications before extracting valuable feedstock and finally re-introducing their nutrients into the biosphere, rounds out the core principles of a restorative circular economy. Figure 6 illustrates how

2. From linear to circular
Continued

FIGURE 6 **The circular economy—an industrial system that is restorative by design**



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

The drive to shift the material composition of consumables from technical towards biological nutrients and to have those cascade through different applications before extracting valuable feedstock and finally re-introducing their nutrients into the biosphere, rounds out the core principles of a restorative circular economy. Figure 6 illustrates how technological and biological nutrient-based products and materials cycle through the economic system, each with their own set of characteristics—which will be detailed later in this chapter.

technological and biological nutrient-based products and materials cycle through the economic system, each with their own set of characteristics—which will be detailed later in this chapter.

Terminology[39]

Reuse of goods
The use of a product again for the same purpose in its original form or with little enhancement or change. This can also apply to what Walter Stahel calls 'catalytic goods', e.g., water used as a cooling medium or in process technology.

Product refurbishment
A process of returning a product to good working condition by replacing or repairing major components that are faulty or close to failure, and making 'cosmetic' changes to update the appearance of a product, such as cleaning, changing fabric, painting or refinishing. Any subsequent warranty is generally less than issued for a new or a remanufactured product, but the warranty is likely to cover the whole product (unlike repair). Accordingly, the performance may be less than as-new.

Component remanufacturing
A process of disassembly and recovery at the subassembly or component level. Functioning, reusable parts are taken out of a used product and rebuilt into a new one. This process includes quality assurance and potential enhancements or changes to the components.

Cascading of components and materials
Putting materials and components into different uses after end-of-life across different value streams and extracting, over time, stored energy and material 'coherence'. Along the cascade, this material order declines (in other words, entropy increases).

Material recycling
• Functional recycling. A process of recovering materials for the original purpose or for other purposes, excluding energy recovery.[40]

• Downcycling. A process of converting materials into new materials of lesser quality and reduced functionality.

• Upcycling. A process of converting materials into new materials of higher quality and increased functionality.

Biochemicals extraction
Applying biomass conversion processes and equipment to produce low-volume but high-value chemical products, or low-value high-volume liquid transport fuel—and thereby generating electricity and process heat fuels, power, and chemicals from biomass. In a 'biorefinery' such processes are combined to produce more than one product or type of energy.

Composting
A biological process during which naturally occurring microorganisms (e.g., bacteria and fungi), insects, snails, and earthworms break down organic materials (such as leaves, grass clippings, garden debris, and certain food wastes) into a soil-like material called compost. Composting is a form of recycling, a natural way of returning biological nutrients to the soil.

Anaerobic digestion
A process in which microorganisms break down organic materials, such as food scraps, manure, and sewage sludge, in the absence of oxygen. Anaerobic digestion produces biogas and a solid residual. Biogas, made primarily of methane and carbon dioxide, can be used as a source of energy similar to natural gas. The solid residual can be applied on the land or composted and used as a soil amendment.

Energy recovery
The conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of so-called waste-to-energy processes, including combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas recovery.

Landfilling
Disposing of waste in a site used for the controlled deposit of solid waste onto or into land.

39 Our understanding of reuse, refurbishing, and cascading is in line with definitions developed by the Centre for Remanufacturing and Reuse (CRR). With respect to remanufacturing, our focus is on recovery at module/component level, whereas the CRR defines remanufacturing as 'returning a used product to at least its original performance with a warranty that is equivalent to or better than that of the newly manufactured product'— Adrian Chapman et al., 'Remanufacturing in the U.K. – A snapshot of the U.K. remanufacturing industry'; Centre for Remanufacturing & Reuse report, August 2010

40 This definition is in line with Article 3(7) of Directive 94/62/EC. This article additionally states that recycling includes organic recycling

2. From linear to circular
Continued

Professor Dr. Michael Braungart
Professor Dr. Michael Braungart is the founder and scientific director of EPEA Environmental Protection and Encouragement Agency, co-founder and managing director of McDonough Braungart Design Chemistry (MBDC), and scientific director of the Hamburger Umweltinstitut (HUI). He teaches at the University of Lüneburg and the Dutch Research Institute for Transitions (DRIFT) of Erasmus University, and is a visiting professor at the Darden School of Business. He teaches process engineering and lectures on topics such as eco-efficiency and eco-effectiveness, Cradle to Cradle® design, and intelligent materials pooling.

Professor Roland Clift CBE FREng
Emeritus Professor of Environmental Technology and Founding Director of the Centre for Environmental Strategy at the University of Surrey; Executive Director of the International Society for Industrial Ecology; past member of the Royal Commission on Environmental Pollution and the Science Advisory Council of Defra.

Professor Walter R. Stahel
Professor Walter Stahel is head of risk management at the Geneva Association. In 1982, he founded the Product-Life Institute, Europe's oldest sustainability consultancy. An alumnus of the Swiss Federal Institute of Technology, Zurich, Stahel has authored several award-winning academic papers and is a visiting professor at the Faculty of Engineering and Physical Sciences at the University of Surrey.

Janine Benyus
Janine Benyus is a natural sciences writer, innovation consultant, and author of six books, including her latest—Biomimicry: Innovation Inspired by Nature. In 1998, Janine co-founded an education and innovation practice called Biomimicry Guild, which has helped clients such as General Electric, HOK Architects, Levi's, NASA, and Seventh Generation create sustainable products, processes, and policies based on nature's principles.

Circular economy—schools of thought

The circular economy concept has deep-rooted origins and cannot be traced back to one single date or author. Its practical applications to modern economic systems and industrial processes, however, have gained momentum since the late 1970s as a result of the efforts of a small number of academics, thought-leaders, and businesses.

The general concept has been refined and developed by the following schools of thought.

Regenerative Design. In the 1970s, an American professor named John T. Lyle launched a challenge for graduate students. Lyle asked students to forge ideas for a society in which 'daily activities were based on the value of living within the limits of available renewable resources without environmental degradation,' according to a California research centre that is now named after Lyle.[41] The term regenerative design came to be associated with this idea—that all systems, from agriculture onwards, could be orchestrated in a regenerative manner (in other words, that processes themselves renew or regenerate the sources of energy and materials that they consume).

Performance Economy. Walter Stahel, architect and industrial analyst, sketched in his 1976 research report to the European Commission *The Potential for Substituting Manpower for Energy*, co-authored with Genevieve Reday, the vision of an economy in loops (or circular economy) and its impact on job creation, economic competitiveness, resource savings, and waste prevention.[42 43] Stahel's Product-Life Institute, considered one of the first pragmatic and credible sustainability think tanks, pursues four main goals: product-life extension, long-life goods, reconditioning activities, and waste prevention. It also insists on the importance of selling services rather than products, an idea referred to as the 'functional service economy', now more widely subsumed into the notion of 'performance economy'. Stahel argues that the circular economy should be considered a framework, and its supporters see it as a coherent model that forms a valuable part of a response to the end of the era of low cost oil and materials.

Cradle to Cradle. German chemist and visionary Michael Braungart went on to develop, together with American architect Bill McDonough, the Cradle to Cradle™ concept and certification process. This design philosophy considers all material involved in industrial and commercial processes to be nutrients, of which there are two main categories: technical and biological. The Cradle to Cradle framework focuses on design for effectiveness in terms of products with positive impact, which fundamentally differentiates it from the traditional design focus on reducing negative impacts.

Cradle to Cradle design perceives the safe and productive processes of nature's 'biological metabolism' as a model for developing a 'technical metabolism' flow of industrial materials. The model puts a particular emphasis on precisely defining the molecular composition of materials—'knowing what you have, which is the basis of every quality-based materials recycling system'. In some cases, notably for technological products that are subject to frequent upgrades, durability is not the optimum strategy—in that instance, it is preferable to design the products in a way that makes their disassembly and the recovery of their components easy, either to upgrade some elements or to use individual parts for the next generation. It is thus important to be able to, for various families of products, define the use period, as it influences their conception: will the object remain in use for ten years or more (washing machine) or rather two (mobile phone)? Product components can be designed for continuous recovery and reutilisation as biological and technical nutrients within these metabolisms. The Cradle to Cradle framework addresses not only materials but also energy and water inputs and builds on three key principles: 'Waste equals food'—'Use current solar income'—'Celebrate diversity'.

Industrial Ecology. Industrial ecology is the study of material and energy flows through industrial systems. Its international society is headed by Professor Roland Clift at the Centre for Environmental Strategy at the University of Surrey. Focusing on connections between operators within the 'industrial ecosystem', this approach aims at creating closed-loop processes in which waste serves as an input, thus eliminating the notion of an undesirable by-product. Industrial ecology adopts a systemic point of view, designing production processes in accordance with local ecological constraints whilst looking at their global impact from the outset, and attempting to shape them so they perform as close to living systems as possible. This framework is sometimes referred to as the 'science of sustainability', given its interdisciplinary nature, and its principles can also be applied in the services sector. With an emphasis on natural capital restoration, industrial ecology also focuses on social wellbeing.

Biomimicry. Janine Benyus, author of *Biomimicry: Innovation Inspired by Nature,* defines her approach as 'a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems'. Studying a leaf to invent a better solar cell is an example. She thinks of it as 'innovation inspired by nature'.[44] Biomimicry relies on three key principles:

- **Nature as model:** Study nature's models and emulate these forms, processes, systems, and strategies to solve human problems.
- **Nature as measure:** Use an ecological standard to judge the sustainability of our innovations.
- **Nature as mentor:** View and value nature not based on what we can extract from the natural world, but what we can learn from it.

41 "History of the Lyle Center", Lyle Center for Regenerative Studies, Cal Poly Pomona (http://www.csupomona.edu/~crs/history.html)

42 The report was published in 1982 as the book Jobs for Tomorrow: The Potential for Substituting Manpower for Energy 98

43 www.performance-economy.org

44 http://www.biomimicryinstitute.org/about-us/what-is-biomimicry.html

2. From linear to circular
Continued

The concept and principles of the circular economy have already been put into practice successfully by very different companies across the manufacturing landscape. Prominent examples include Michelin, Caterpillar, Renault, Ricoh, and Desso.

• In the 1920s, **Michelin** pioneered leasing tyres under a pay-per-kilometre programme. As of 2011, Michelin Fleet Solutions had 290,000 vehicles under contract in 23 countries, offering tyre management (upgrades, maintenance, replacement) to optimise the performance of large truck fleets—in Europe, 50% of large truck fleets externalise their tyre management. By maintaining control over the tyres throughout their usage period, Michelin is able to easily collect them at end of the leases and extend their technical life (for instance by retreading) as well as to ensure proper reintegration into the material cascade at end of life.

• **Caterpillar** created its remanufacturing division in 1972; it has kept on growing ever since—over the last decade at a brisk 8 to 10%, well above the growth rate of the global economy as a whole. It now has a remanufacturing portfolio of hundreds of parts and handled more than 70,000 tonnes of remanufactured products in 2010, up from 45,000 tonnes in 2005. Growth is expected to continue as Caterpillar's engineers are working systematically through its backlog of warehoused used parts to bring them back into economic use.[45]

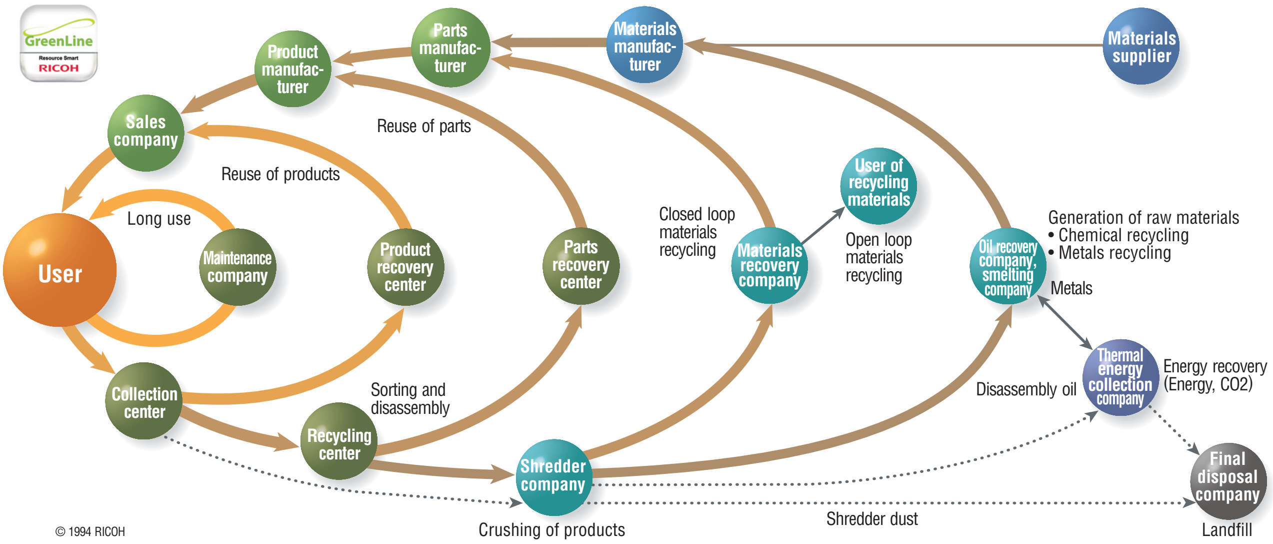
• From its start in a suburban garage in 1898, **Renault** has grown into a leader, first in automotive engineering and now also in remanufacturing. It operates a dedicated remanufacturing plant near Paris, France. There, several hundred employees re-engineer 17 different mechanical subassemblies, from water pumps to engines. Renault works with its distributor network to obtain used subassemblies, and supplements these with used parts purchased directly from end-of-life vehicle disassemblers as well as with new parts where necessary. Renault's ability to structure and run its reverse logistics chain and access a steady stream of cores, together with its deployment of highly skilled labour, has allowed the company to grow its remanufacturing operations into a 200 million euro business.

• **Ricoh,** provider of managed document services, production printing, office solutions and IT services, is another Fortune 500 company, active in 180 countries. It developed 'GreenLine' as part of its Total Green Office Solutions programme, which aims to minimise the environmental impact of products at its customers' sites. Copiers and printers returning from their leasing programme are inspected, dismantled, and go through an extensive renewal process—including key components replacement and software update—before re-entering the market under the GreenLine label with the same warranty scheme that is applied to new devices. Because it increases customers' choice, Ricoh's GreenLine programme has quickly become a success story and it now keeps pace with Ricoh's new equipment sales.

• After buying out the company, the top management team at **Desso** took inspiration from the Cradle to Cradle™ movement and decided to pursue C2C Certification℠ for the entire company. A major spur to innovation and an inspiration for both customers and employees, Desso's broad adoption of circular economy principles has been driving top-line growth. After the buyout in 2007, its European market share for carpet tiles grew from 15 to 23% and profit margins (normalised EBIT of the original carpet business) from 1 to 9%, with about half of this gain directly attributable to the introduction of C2C™ principles. In its ambition to change over the complete system rather than cherry-pick individual measures, Desso is also phasing in renewable energy sources for each of its production sites—in line with another core C2C™ principle.

45 Corporate annual reports 2005 to 2010; Product-Life Institute website (http://www.productlife.org/en/archive/case-studies/caterpillar-remanufactured-products-group)

FIGURE 7 **The circular economy at work: Ricoh's Comet Circle™**



Resource Recirculation at Ricoh

In 1994, Ricoh established the Comet Circle™ as a catalyst for change. It expresses a comprehensive picture of how Ricoh can reduce its environmental impact, not only in its activities as a manufacturer and sales company, but also upstream and downstream—along the entire lifecycle of its products. The Comet Circle™ centres on the belief that all product parts should be designed and manufactured in a way that they can be recycled or reused. Ricoh management uses the Comet Circle™ as a real tool to plan its portfolio of products and activities. It is on this basis that Ricoh established the GreenLine label as a concrete expression of its resource recirculation business, with the priority focus on inner-loop recycling.

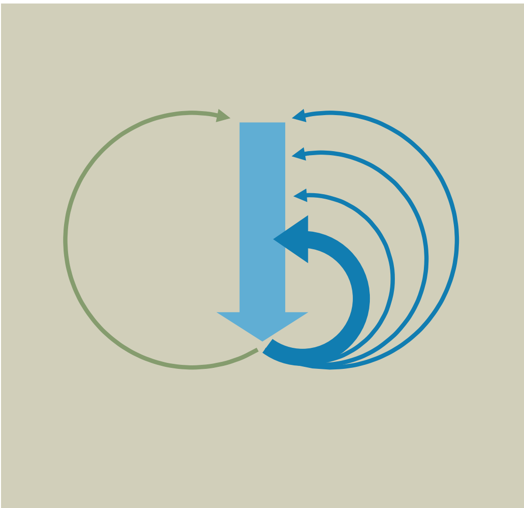
The benefits of moving on a 'tighter loop'—long use and reuse (the left side of the Comet Circle™) —are manifold for Ricoh, from enhancing its product portfolio with lower-cost models and serving a wider range of customers to rendering its offering more competitive by mixing 'new' and recirculation equipment.

Its evolved relationship with its products in use is producing further results: optimising the years that machines are in operation at customer sites and generating annuity; generating additional revenue and margin by selling equipment more than once; and of course making a considerable contribution to resource conservation. Ricoh's objectives are to reduce the input of new resources by 25% by 2020 and by 87.5% by 2050 from the level of 2007; and to reduce the use of—or prepare alternative materials for—the major materials of products that are at high risk of depletion (e.g., crude oil, copper, and chromium) by 2050.

2. From linear to circular
Continued

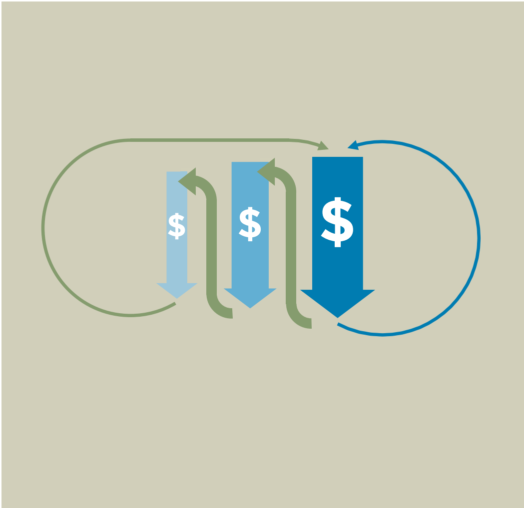
Sources of value creation in a circular economy

The principles of the circular economy offer not only a description of how it should work as a whole, but also an outline of specific sources of core economic value creation potential. The economics and comparative attractiveness of different circular setups (e.g., reuse versus remanufacturing versus recycling) can differ significantly for different products, components, or types of material, whether in a specific geography or segment of the (global) supply chain—all of which we spell out in the next chapter. Nevertheless, there are four simple principles of circular value creation that hold true.

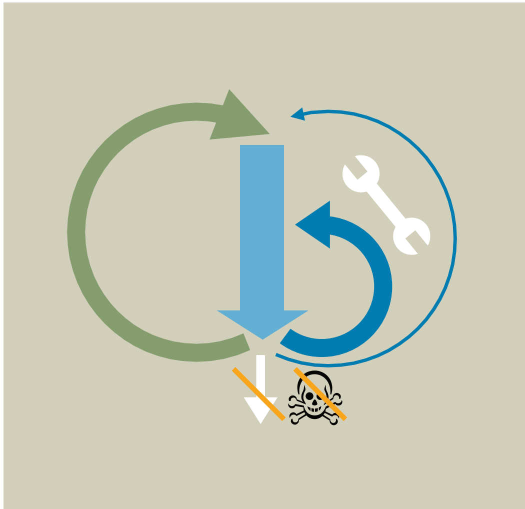


Power of the inner circle: In general, the tighter the circles are, the larger the savings should be in the embedded costs in terms of material, labour, energy, capital and of the associated rucksack of externalities, such as GHG emissions, water, or toxic substances (Figure 8). Given the inefficiencies along the linear supply chain, tighter circles will also benefit from a comparatively higher virgin material substitution effect (given the process inefficiencies along the linear chain). This arbitrage opportunity revealed by contrasting the linear to the circular setup is at the core of their relative economic value creation potential. Whenever the costs of collecting, reprocessing, and returning the product, component or material into the economy is lower than the linear alternative (including the avoidance of end-of-life treatment costs), setting up circular systems can make economic sense. With increasing resource prices and higher end-of-life treatment costs, this arbitrage becomes more attractive, especially in the beginning when the economies of scale and scope of the reverse cycle can benefit from higher productivity gains (because of their low starting base given that many reverse processes are still subscale today).

Power of circling longer: A second core value creation potential stems from keeping products, components, and materials in use longer within the circular economy. This can be done by either going through more consecutive cycles (e.g., not only one refurbishment of an engine core but multiple consecutive ones) or by spending more time within a cycle (e.g., extending the use of a washing machine from 1,000 to 10,000 cycles). This prolongation of usage will substitute virgin material inflows to counter the dissipation of material out of the economy (which, assuming constant demand and given the second law of thermodynamics, i.e., ‘matter is decaying towards entropy’, will eventually happen). Here, too, rising resource prices render this value-creation lever more attractive. Increased operating and maintenance costs, however, and/or losing out against efficiency gains due to rapid innovation of the product, could eat up this positive arbitrage potential.



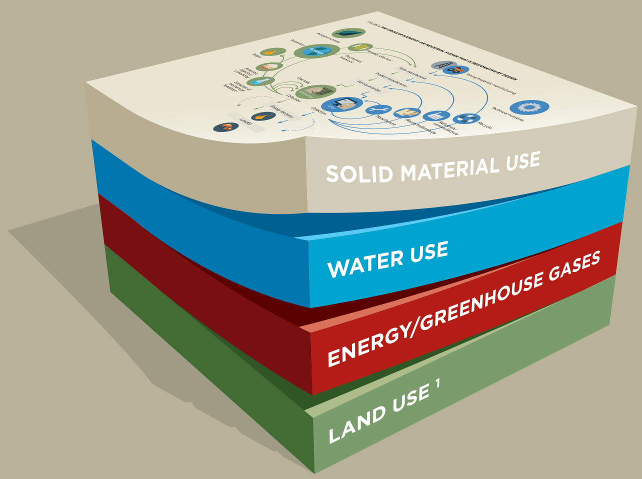
Power of cascaded use and inbound material/product substitution: While the previous value creation levers refer to reusing identical products and materials within the circular setup for a specific product, component or material category, there is also an arbitrage opportunity in the cascading of products, components or materials across different product categories (Figure 9) (e.g., transforming cotton-based clothing into fibrefill for furniture and, later, into insulation material before returning it as a biological nutrient safely into the biosphere). In these cascades, the arbitrage value creation potential is rooted in the lower marginal costs of reusing the cascading material as a substitute for virgin material inflows and their embedded costs (labour, energy, material) as well as externalities against the marginal costs of bringing the material back into a repurposed use.



Power of pure, non-toxic, or at least easier-to-separate inputs and designs: The power of this fourth major lever is a further enhancement to the above-mentioned value creation potential and offers an additional host of benefits. To generate maximum value, each of the above levers requires a certain purity of material and quality of products and components. Currently, many post-consumption material streams become available as mixtures of materials, either because of the way these materials were selected and combined in a previous single product or because they are collected and handled without segmentation and without regard for preserving purity and quality (e.g., in municipal waste collection). Scale economies and efficiency gains in the reverse cycle can be obtained through improvements in the original design of products—such as ease of separation, better identification of embedded components, and material substitution—and in the reverse processes—such as reduced product damage rates during collection and transportation, lower reconditioning scrap rates, and reduced contamination of material streams during and after collection. These improvements to the product and the reverse cycle process translate into further reductions of the comparative costs of the reverse cycle while maintaining nutrients, especially technical ones, at higher quality throughout the cycles, which typically extends longevity and thus overall material productivity. Beyond the performance of the reverse cycle, keeping toxic materials out of the product design can bring other measurable advantages. When Desso, for example, decided to eliminate all toxic chemicals in its carpet tiles—in line with Cradle to Cradle principles—its business benefited from an uptake in the aviation market, where carpet offgassing can affect passenger health and comfort.

2. From linear to circular
Continued

FIGURE 8 **The impact of more circular production processes accumulates across several layers of inputs**



1 Including impact on biodiversity and ecosystem services
Source: Ellen MacArthur Foundation circular economy team

Long-term effects of circularity on material stocks and mix

The combined effect of these value creation levers will profoundly change for the better both the mix as well as the run rate at which our extracted material stocks will grow. To illustrate these long-term effects, we prepared a simple theoretical example consisting of a single product (made of one material) over a 30-year time frame with and without reverse cycles. We first modelled the business-as-usual (BAU) scenario and then modified this scenario by gradually introducing the circular value-creation levers.

For the **circular** scenario, we assumed that:

• We have the same efficiency losses along the value chain from one product step to the next as for BAU

• We face the same demand growth of 3% p.a., but:

• We build up reverse cycle treatment capacities, also at the rate of 4 percentage points per annum, with a cap at 40% each for reuse/refurbishment and remanufacturing for the end-of-life flows

• We recycle the share of the collected material that exceeds the 40% limits on our reverse treatment capacities

• We are able to increase each of the reuse, refurbishment, and remanufacturing cycles by an additional cycle, i.e., instead of discarding the product after the first two years, we can run the product through an extra cycle before it becomes unfit for purpose (given wear and tear or any of the other limits to repeated use—see sidebar on the factors driving premature obsolescence).

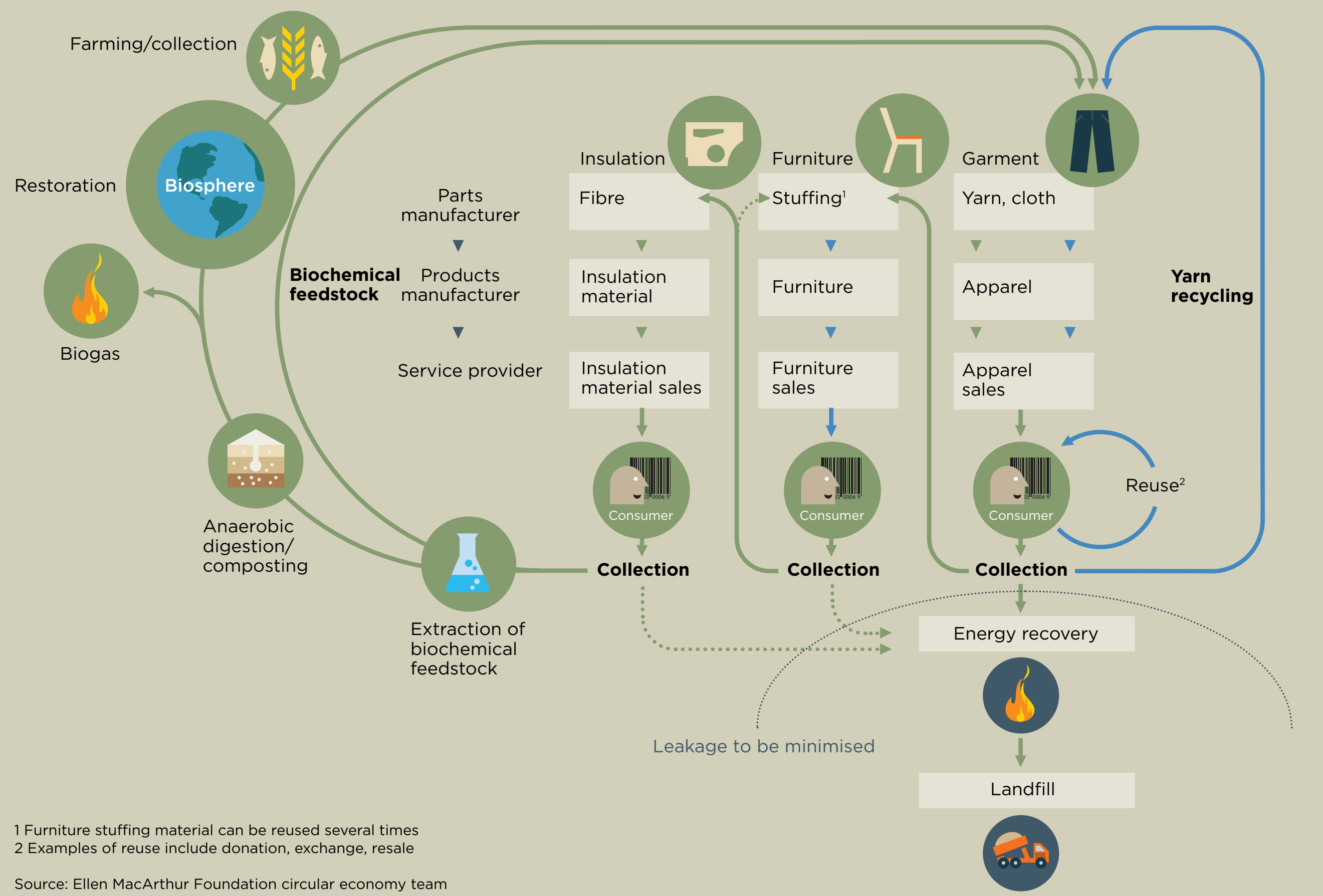
The differences between the BAU and the circular scenarios for both new virgin material required and the build-up of stock highlight the substantial savings effect of the circular setup (Figure 10).

• **Need for virgin material extraction would decrease substantially.** The impact of a circular set-up on virgin material extractions needs is considerable. This does not represent a temporary effect—the widening spread between the two lines continues even after growing collection rates and reuse/refurbishing rates come to a plateau (a point which can be seen visually as the 'kink' in the line that represents circular demand).

• **Growth of landfill and total material stock would decrease** as a consequence of these substitution effects. Most importantly, the growth rate would not resume the same speed of material demand as in the BAU scenario, as the substitution at product level will proportionally save more raw material than a comparative product created from virgin material. As a result the underlying run rates are reduced.

This model assumes that, at any of these stages, the economic trade-offs between the cost of virgin inputs and the cost of material that has been kept in the cycle via circular streams would always favour the circular setup. Obviously, this would not hold true if the price of the virgin material is at a level below the cost of keeping materials in the reverse cycles. Other trade-offs must be considered as well. As Peter Guthrie, who leads the Centre of Sustainable Development at Cambridge University's Department of Engineering, puts it: 'There will always need to be consumption of virgin materials, and the process of

FIGURE 9 **Cascading keeps materials in circulation for longer—textile example**



1 Furniture stuffing material can be reused several times
2 Examples of reuse include donation, exchange, resale

Source: Ellen MacArthur Foundation circular economy team

cycling will always require some energy use. The balance of resource use for different options needs to be carefully considered.' Still, Guthrie says, 'The whole approach of circularity is precisely the direction of travel for improved sustainability performance.'

To provide a perspective on how robust this arbitrage opportunity is in practice, Chapter 3 examines the effects and costs of reverse treatments and disposal options for a number of selected products in detail, and identifies what building blocks need to be put in place to capture the potential benefits. Chapter 4 then assesses how large this potential could be if scaled up across the economy. Chapter 5 puts forward strategies that will allow companies to extract maximum value from moving towards more circular business models.

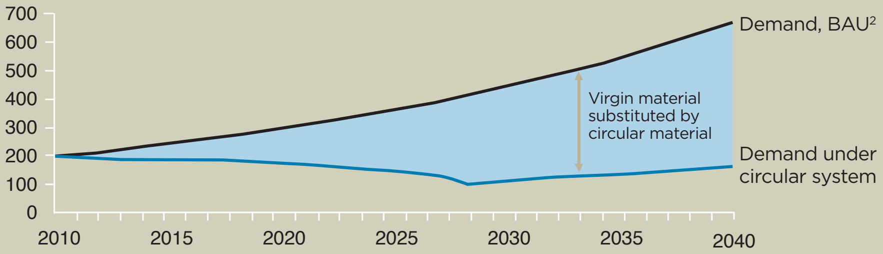
The time seems right, now, to embrace more widely and accelerate the circular design philosophy. Resource prices are soaring, and the implicit or explicit costs of disposal drastically increasing. At the same time, progress in technologies and material science is yielding longer-lasting and more reusable designs whilst increased visibility along the value chain enables better tracking of the whereabouts of products and materials, and consumers and corporations have grown more accustomed to commercial practices based on performance instead of ownership.

2. From linear to circular
Continued

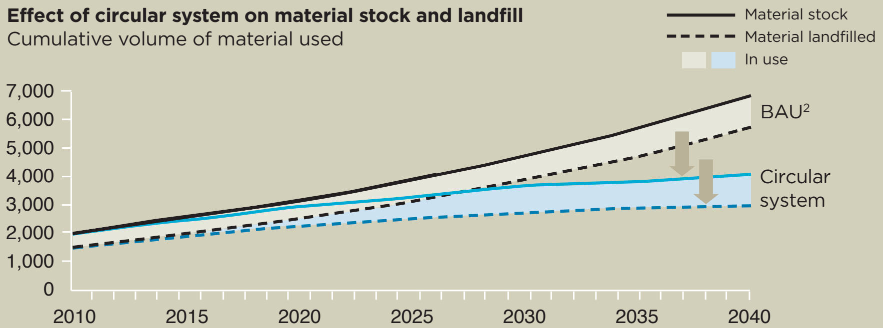
FIGURE 10
A circular economy would not just 'buy time'—it would reduce the amount of material consumed to a lower set point

ILLUSTRATIVE

Effect of circular system on primary material demand in widget market[1]
Volume of annual material input required



Effect of circular system on material stock and landfill
Cumulative volume of material used



1 Assumptions: Widgets have a 5-year product life; demand for widgets assumed to grow at 3% p.a.; collection rate rises from 0% in 2010 to 90% in 2040; reuse and refurbishment rates scale up over time, from 0% to 40% each; all collected material that is not reused or refurbished is recycled
2 Business as usual

SOURCE: Ellen MacArthur Foundation circular economy team

3

How it works up close

Case examples of circular products

Demonstrates through detailed case studies the many ways in which companies can benefit from circular business models and the key building blocks needed on a systemic level to shift business in this direction.

3. How it works up close
Case examples of circular products

It is evident that reuse and better design can significantly reduce the material bill and the expense of waste disposal and that they can create new enterprises and more useful products—meeting needs of new customers as the population grows. But—from an economics perspective—can these advantages match the advantages of products designed for mass production based on low labour costs and economies of scale? From a business and consumer perspective—can producing, selling, and consuming less material be a more attractive proposition? Our treatment of these questions in the pages that follow is in many ways a 'sixteenth century map' of the circular economy, a rough chart of its potential. It is our hope that this analysis will entice companies to embark on this journey, and, in that process, refine it with an ever-more solid base of evidence—not only by demonstrating its terrific potential, but also by testifying to the trials and tribulations of a transformation into the circular economy.

To demonstrate the economic opportunity of such a model, EMF and its partners analysed the options for several different categories of resource-intensive products—from fast-moving consumer goods such as food and fashion, to longer-lasting products such as phones, washing machines, and light-commercial vehicles, and including single-family houses as an example of a long-life product. Because the service sector is not a converter of materials, services as such are not directly affected by the adoption of circularity principles. Thus we do not cover services in our analysis—although it is worth noting that as a purchaser of products, the sector could have a considerable impact in bringing about change, and of course the circular economy would greatly expand the need for services. While the shift towards renewable energy is a key principle of the circular economy, a full assessment of the impact of a circular transition on the energy sector is also outside the scope of this report, and the analysis excludes energy and other utilities as producing sectors.

Instead, we have selected a broad range of manufactured products to illustrate the various design choices and business model changes that may help companies reap the benefits of a more circular product and service portfolio. For some complex products, we go into more detail, because it is here where the case is most difficult to make. The sector focus of these analyses is on manufacturing and, here, the final production stage of the value chain. In other words, we do not analyse the economic effects on upstream participants in the market. Within manufacturing, we examined an intentionally wide range of product types. Given the starkly different characteristics of short-lived manufactured goods (such as, say, food packaging) versus long-lived manufactured goods (e.g., material used in housing construction), we intentionally chose products in both categories, as well as a mid-range, medium-lived category.

Our analysis leads us to believe that this final category, medium-lived products—and specifically, complex medium-lived products—is a sweet-spot segment for circularity. These, then, are the products we examine in full depth with our circularity calculator (for details on the analysis, see sidebar). The eight sectors that produce these and similar types of products represent 48.6%, or nearly half, of the GDP contribution of the manufacturing sector within the EU economy, demonstrating that circular business activities have the potential to outgrow its their 'niche' status and become relevant in the mainstream economy.[46]

In the pages that follow, we describe at length our analysis of products in our 'sweet spot' sectors, namely mobile phones, smartphones, light commercial vehicles, washing machines—for which we applied the circularity calculator—and power tools. We also discuss the potential for circularity across the broader economy, from the long-lived (e.g., buildings) to consumables (e.g., packaging and food products), parts of the manufacturing sector, and calculate a cascade for textiles as an example of short-lived products.

46 GDP contribution based on Eurostat Input/Output tables 2007 for EU-27 economies

Buildings—Mastery of reverse cycle skills can make all the difference

While many long-lived assets such as buildings and road infrastructure consist largely of metals, minerals, and petroleum-derived construction materials (i.e., technical nutrients), there is also a significant role for bio-based materials such as various kinds of wood. Whatever the source and character of the nutrient, we see that the circularity potential for such long-lived assets has gone largely untapped, resulting in a great loss of volume and value, as discussed earlier in this text. Various initiatives have demonstrated the potential for value retention—the findings of one such pilot in Riverdale, MD (USA) and the order of magnitude of the improvement potential it demonstrates can be considered typical.[47] The pilot initiative showed that deconstructing rather than demolishing U.S. houses built in the 1950s and 1960s would divert 76% of the rubble produced from going to landfill—thereby avoiding the associated landfill cost and preserving valuable building components and materials for recycling and reuse. Moreover, deconstruction case studies have shown important social benefits, including significant increases in labour requirements,[48] job creation at a local level,[49] and better employment conditions and educational opportunities.[50] As an illustration, Brian Milani estimated that, *'If deconstruction were fully integrated into the U.S. demolition industry, which takes down about 200,000 buildings annually, the equivalent of 200,000 jobs would be created'.*[51]

Leading construction companies such as Skanska, a Swedish project development and construction group with worldwide activities, have made the possibilities of deconstruction an inherent part of their strategy and services portfolio. In Japan, Kajima Construction Corporation developed a new deconstruction technique that allowed it to recycle 99% of the steel and concrete and 92% from a building. The Japanese government has supported deconstruction through both legislation and policies that stimulate. In the U.S., local, state, and federal agencies have started to encourage deconstruction programmes for their beneficial effects on employment and community building. It may be for this reason that private sector take-up has been limited, and deconstruction activities are currently largely the domain of smaller local players.

Medium-lived complex products—The heart of the opportunity

In contrast to long-lived products, such as buildings or bridges, the sectors we focus on generally include products that are in use for a short enough timeframe that they are subject to frequent technological innovation, but long enough that they are not subject to one-off consumption. Most products in these sectors contain multiple parts and therefore are suitable for disassembly or refurbishment. Finally, this portion of the economy is quite large—the eight sectors we focus on account for about USD 1.98 trillion in final sales in the EU-27, or a little less than half of the region's final sales from manufacturing.[52] The eight sectors, as categorised by Eurostat, are as follows: machinery and equipment; office machinery and computers; electrical machinery and apparatus; radio, television, and communication equipment and apparatus; medical, precision and optical instruments, watches and clocks; motor vehicles, trailers, and semi-trailers; other transport equipment; and furniture and other manufactured goods.[53]

47 NAHB Research Center, Deconstruction—Building Disassembly and Material Salvage: The Riverdale Case Study, June 1997. Prepared for U.S. EPA Urban and Economic Development Division

48 Charles J. Kibert et al., Implementing deconstruction in the United States

49 DiRamio et al. http://www.bigideasforjobs.org/

50 Frank Regan, Rochester Environmental News Examiner, 2010

51 Brian Milani, Building Materials in a Green Economy: Community-based Strategies for Dematerialization, 2001

52 Final uses at basic prices (e.g., excluding shipping costs, customisations, etc.), from Eurostat Input/Output tables 2007 for EU-27 economies

53 It is worth noting that these sectors each contain dozens and, in some cases, hundreds of specific product types. Not all product types fit all the criteria we outline—some, for instance, have relatively shorter or longer lifespans; others have only one or two components and are not particularly complex. That said, utilising these sectors as a proxy allows us to roughly define the size of the economy that would be affected by circular production methods

3. How it works up close
Continued

The Circularity Calculator

In order to calculate the economic impact of moving to a circular system at the product level, we applied a 'circularity calculator' analysis to each of our selected products. In simple terms, this analysis compares the inputs needed to make a new product in today's system (the 'linear' product) with those that would be needed to make the same product using circular economy principles (the 'circular' product).

The analysis focuses on five key areas of economic and environmental impact, each of which relates to the broader benefits of circularity discussed earlier in this document.

The five areas are:
Material inputs. For each product, we compared the material intensity of a 'linear' version, discarded by its first owner, with the material intensity of a 'circular' version, for which we calculated and factored in various forms of circular options (reuse, refurbishing, remanufacturing, recycling). We compared materials in dollar terms, as tonnages would fail to account for the differing values of different input materials.

Labour inputs. For each product, we considered the labour required to make a new product versus the labour required to make a circular loop (i.e., to refurbish, remanufacture, recycle, or otherwise reuse the product).

Energy inputs. For each product, we considered the difference in energy required to make a new product versus a circular product.

Carbon emissions. For each product, we considered the carbon footprint of the process of manufacturing a new product versus the emissions generated to make a circular loop.

Balance of trade. For each product, we considered which inputs are imported into the European Union, for the production process of both linear and circular versions.

We took the results of our analysis in each area above, for one of our specific products in each case, and combined them with informed assumptions to determine the total savings on material, labour, energy, and carbon emissions as well as the trade balance effect at market level, if producers across the product industry (e.g., the mobile phone market) were to adopt circular production techniques.

Our analysis shows that, for the products selected (mobile phones, smartphones, light commercial vehicles, and washing machines), circularity can be profitable on a product-specific level—and that it could make a significant economic impact at the level of the product market.

Our initial analysis explicitly excluded any consideration of the profits of individual companies. Instead, we focused on effects at an industry level—as we believe the competitive structure would likely change during a shift to a circular economy. Further analysis at the company level, however, has demonstrated that adopting circular techniques would likely prove profitable for individual companies as well, even with a certain degree of demand substitution of existing products.

We ran our circularity calculator for two scenarios:
- A more conservative **'transition scenario'**, where we make assumptions mainly on changes in product designs and reverse supply chain skills. We typically assumed improvements in underlying economics, collection rate increases of 20 to 30 percentage points, and a roughly 30 percentage point shift from recycling to refurbishing or remanufacturing activities.
- An **'advanced scenario',** showing the potential effect of a world that has undergone more radical change and has further developed reverse technologies and infrastructure and other enabling conditions such as customer acceptance, cross-chain and cross-sector collaboration, and legal frameworks. Our analyses assumed further collection rate increases of 30 to 40 percentage points and an additional 5 to 10 percentage points shift to refurbishing or remanufacturing.

The key data and assumptions underlying our circularity calculator analyses for the selected products are outlined in the appendix.

Mobile phones—Extracting lasting value out of fashionable items

With 1.6 billion mobile phones produced in 2010, more phones are entering the market than there are consumers.[54] As a result, in mature markets (Western Europe, North America, Japan) consumers own 1.1 mobile phones and average usage time is down to less than 2.5 years.[55] In emerging markets, the sector is nevertheless still poised for growth.

In 2010, Waste Electrical and Electronic Equipment (WEEE) volumes in the EU-27 for IT and telecommunications equipment were estimated at 750 thousand tonnes. Over the next four years, total WEEE volumes in the EU-27 are expected to grow cumulatively by more than 10%.[56] Yet looking at volumes of waste generated does not reveal the true value embedded in consumer electronics waste. While not being particularly significant in terms of weight, mobile phone waste has considerable value embedded in its materials and components. Typically weighing less than 150 grams, a mobile phone is packed with valuable materials such as gold, silver, and rare earth metals. Given today's low collection and recycling rates, nearly all of this material is lost. In Europe alone, for example, 160 million discarded but uncollected devices represent a material loss of up to USD 500 million annually. With collection rates in Europe hovering around 15% and mobile phone designs becoming increasingly integrated, there is hardly any component reuse or remanufacturing, and the secondary mobile phone market (while fast growing) is almost negligible at around 6% of the primary market.[57]

In order to understand the economic implications of circular activities in the mobile phone market, we applied our circularity calculator to a standard low-cost mobile phone valued at USD 36.[58] We first assessed the economics of different circular options for mobile phones and subsequently considered associated environmental benefits (with a focus on carbon emission savings).

In today's world with low collection rates, partially attributable to contract schemes that, in the majority of cases, do not require customers to trade in old devices after the typical 24-month period, we did not identify a lot of economic potential except for the obvious phone resale. Yet this circular option also suffers under today's limited return incentives and inadequate reverse logistics, in that many collected devices are in poor condition both functionally and in terms of appearance. Further, demand for used devices strongly varies between handset make and model.

With the advent of shortages of some rare earth[59] and precious metals, the recycling of mobile phones has gained momentum over the past year. Now, the share of phones being channelled to recycling has risen to 9%, but only a small fraction of the more than 20 different materials they contain is ultimately recuperated.[60]

To maximise the economic benefit of keeping mobile phones or at least certain components in a tighter circle at a profit for the manufacturer, only a few things would need to change in the short term (Figures 11A, 11B):

Improving overall collection from 15% to 50% (close to the proposed WEEE regulation target of 65% by 2016).[61] A better collection system would allow manufacturers, remanufacturers, and vendors to gain scale, which would justify investments in larger, more streamlined facilities and hence further improve the attractiveness of these circles by increasing their efficiency. Collection can be encouraged with lease/buy-back models, an improved customer dialogue, and, under certain circumstances, with deposit system, and will need to be complemented with more semi-automated treatment and extraction systems or better pre-sorting before shredding (to catch reusable phones and materials). For greater efficiency when moving into the 'advanced' circularity stage, the phone industry would need to form joint collection systems (e.g., with original equipment manufacturers (OEMs), operators, retailers, manufacturers, reverse logistics companies). Such concerted efforts are essential to fully overcome interrelated quality leakage points along all reverse value chain steps.

54 Gartner statistics on mobile device sales, February 2011

55 CIA World Economic Factbook, 2011

56 Jaco Huisman et al., 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment – Final Report, United Nations University working paper, August 2007; Jaco Huisman, WEEE recast: from 4kg to 65%: the compliance consequences, United Nations University working paper, March 2010

57 U.S. Environmental Protection Agency (EPA), Electronics Waste Management in the United States Through 2009, EPA working paper, May 2011; Eurostat, WEEE key statistics and data, 2011

58 'Basic mobile phones' include low-cost phones and basic communication devices as defined by Gartner and excludes smartphones. For our calculations, we considered a sample of four mobile phones selling at prices between USD 30 and 60 before VAT

59 Rare earth elements contained in mobile devices include Neodymium, Terbium, and Erbium—Marc Humphries, Rare Earth Elements: The Global Supply Chain, Congressional Research Service Report, September 2010

60 Roland Geyer and Vered Doctori Blass, 'The economics of cell phone reuse and recycling', International Journal of Advanced Manufacturing Technology, 2010, Volume 47, pp. 515-525

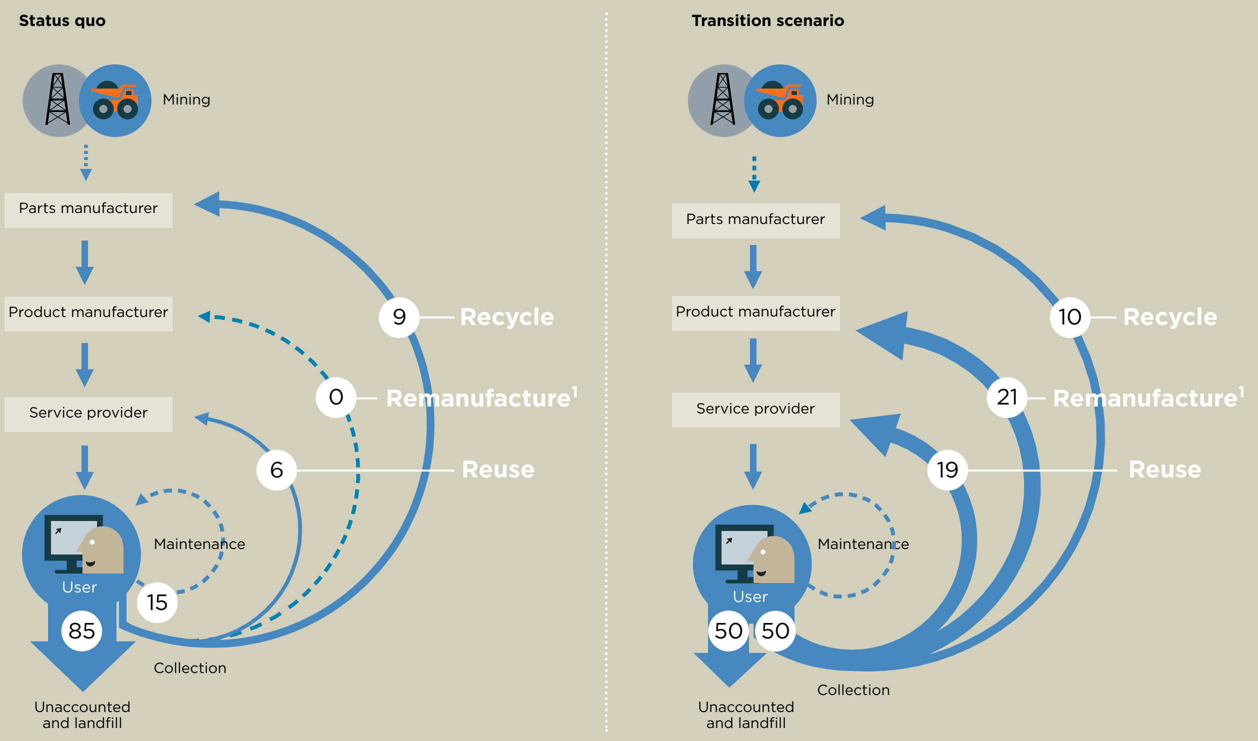
61 European Commission, 'Proposal for a Directive of the European Parliament and of the Council on Waste Electrical and Electronic Equipment (WEEE)', Proposal for a directive, COD 2008/0241, December 2008

3. How it works up close
Continued

FIGURE 11A
Mobile phones: Reuse and remanufacturing as a viable alternative to recycling

ESTIMATES

End-of-life product flows based on 2010 EU figures
Percentage of total end-of-life devices



1 Remanufacturing, here refers to the reuse of certain components and the recycling of residual materials
SOURCE: Gartner; EPA; Eurostat; UNEP; Ellen MacArthur Foundation circular economy team

Selling the entire phone 'as is' after minimal cleaning and repackaging. Our analysis shows that a second-hand vendor can realise a profit of USD 6 (30% margin) per device, even if placing the product on the market with a 40% discount and spending USD 17 on return collection (including buy-back incentive), remarketing, and processing. A used-phone market would benefit from guarantees to customers that manufacturers have software to completely erase a customer's personal data after use, as well as from material choices that extend the life of the product 'core'.

Stripping out reusable components and implementing required design changes to do this more easily. Of the 10 to 12 major components of a standard mobile phone, the top candidates for remanufacturing are the camera, display, and potentially the battery and charger. They are among the most valuable parts within a phone, are comparatively easy to disassemble, and could be used in the production of new devices or in aftermarkets. Key factors for making such a circular treatment economically and technically feasible are standardising components such as displays, cameras, and materials across models and potentially brands through agreement on industry standards; moving to disassembly-friendly product designs (e.g., easy-access, clip-hold assembly instead of adhesives) to enhance the ratio between the value of the material and components reclaimed and the labour needed to extract it; and making reverse supply-chain processes more automated.

As shown in Figure 11B, we estimate that the costs of remanufacturing low-cost mobile phones could be cut by around 50%[62] per device from their current level (e.g., USD 1.0 for collection and transport, USD 3.5 for disassembly, and USD 1.9 for initial screening) when proposed changes of the transition scenario can be realised. In addition, costs occurring in the reuse and recycling process could be reduced by USD 0.7, through more efficient transport and initial screening. In such a scenario, remanufacturing would yield material input cost savings of almost 50% in the final phone production process. Functional recycling could save up to 20% of material input costs and reusing the entire phone does not require any direct material input.

While a value of USD 6 to 7 per phone sounds negligible and is typically lower than the average profit margin on a new standard low-cost phone (up to 25% of the selling price), capturing a significant fraction of the value in the 190 million collected and uncollected end-of-life mobile phones in Europe, many of which could produce value like that shown in our case study, can be economically attractive for third parties as well as manufacturers. From the OEM perspective, the resale market is to a certain extent a threat to sales of new products. In contrast remanufacturing activities on a component level reduce material costs by incremental manufactured components and will not pose a threat to sales of new products as long as the latter are offered as 'new' and without a discount. Such circular business practices also offer a solution to the widespread problem of exporting consumer electronic waste and improper end-of-life treatment in developing countries. By increasing their circular activities, manufacturers could thus also benefit from a more positive public perception.

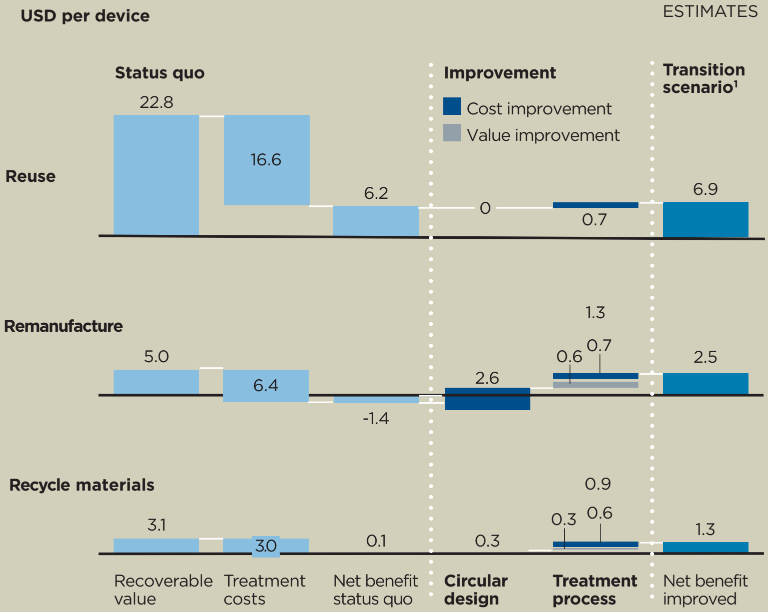
From a macroeconomic perspective, the transition to a circular economy has major implications for material and energy consumption as well as for the balance of trade in the European mobile phone market. In a transition scenario in which 50% of devices are collected (of those, 38% are reused, 41% are remanufactured, and 21% are recycled), market-wide savings on manufacturing material costs could add up to USD 1 billion (~30% of total industry material input costs), and manufacturing energy costs savings to USD 60 million (~16% of total industry energy input costs) a year. These savings refer to costs incurred in the phone production process; further savings occur in upstream value chain steps.[63] In an advanced scenario with 95% collection and an equal split between reuse and remanufacturing, material and energy savings are estimated to be more than USD 2 billion on material and USD 160 million on energy annually, both net of material and energy used in the reverse-

62 Costs for the entire disassembly process could be reduced by ~USD 2.5 per phone; an additional USD 0.8 per phone could be saved in collection and transport, as well as in the initial screening process

63 Metal recycling leads to reduced energy consumption in the extraction phase. but is implicitly considered in the material value of recycled metals, not in energy cost savings

3. How it works up close
Continued

FIGURE 11B
Mobile phones: Design changes and investments in reverse infrastructure could greatly improve the circular business case



1 Transition scenario: Conservative assumptions on improvements in circular design and the reverse cycle, within today's technical boundaries

SOURCE: Geyer & Doctori Blass (2008); Neto & Bloemhof-Ruwaard (2009); Neira et al. (2006); EPA; Umicore; LME; Metal Bulletin; recellular.com; amazon.com; recyclemobilephones.co.uk; Ellen MacArthur Foundation circular economy team

cycle process. Taking into consideration the material extraction and whole manufacturing process of parts and product, greenhouse gas emission savings from circular activities could amount to 1.3 million tonnes of CO_2e in a transition state and around 3 million tonnes (or 65% of primary production emissions) in the case of 95% collection.

While primary mobile phone production is largely located outside Europe, resellers and recycling firms are typically geographically close to the market. As remanufacturing activities also include the recycling of residual material, the process is assumed to take place within Europe (also in order not to confront the topic of illegal e-waste export—though a case could also be made for re-export markets, given labour cost differentials). As a result, circular business practices would have a positive USD 1 to 2 billion effect on Europe's trade balance surplus due to overall reduced imports of new phones and component and material inputs.

Pushing the concept further by improving designs to bring more components into the remanufacturing loop, enabling mobile phones to cycle not only once but potentially multiple times through a product life cycle could even lead to further optimisation potential and further decrease material and energy input costs in the market.

Smartphones—Making the 'smart' in smartphone last longer

Although smartphones and basic mobile phones belong to the same product category, they differ in terms of design, functionality, value, and options for circular business. Smartphones generally feature more advanced technology and a broader range of functions. Smartphones cost on average around USD 400, but prices can reach USD 600 to 700. Material costs for OEMs are typically around USD 100 to 130 per device.[64] The higher value of smartphones compared with basic mobile phones does not stem from costlier raw material inputs but from the value added by technologically advanced components and software. The smartphone market has experienced significant growth in recent years and is expected to grow by 15% per year in Europe between 2010 and 2014.[65]

Given the high value of embedded components, making the reverse circle as short as possible is essential to capturing the full circularity potential of smartphones. Depending on a device's condition, resale after refurbishment is a viable business opportunity as secondary market prices are estimated to be up to 60% of the original price. This stands in contrast to refurbishment opportunities for basic mobile phones, for which, under current market conditions, refurbishment costs typically outweigh potential sales profits. The economic benefit that can be drawn from recycling smartphones, by comparison, is similar to that of basic mobile phones, given that the processes involved and the value of the embedded raw materials is similar for both products.

Refurbishment in the business-to-busines (B2B) context. Circular treatment of smartphones is a particularly interesting option in a B2B context, where fashion takes a backseat to functionality. Businesses that supply their employees with smartphones also typically have well-established mechanisms in place for end-of-life collection. As organising reverse logistics is one of the most complicated tasks in setting up a circular market for mobile devices, smartphones have a head start in business settings because businesses can bundle smartphone purchases and returns, effectively shortening the distance between vendors and customers. Additionally, companies often keep track of their assets more systematically than individuals, another factor contributing to higher potential collection rates. Major players in the smartphone market estimate the current collection rates for smartphones to be around 20%.

Once an end-of-life smartphone has been collected, refurbishment is a financially interesting treatment option, given the high potential resale value. The costs of refurbishment are not insignificant—replacing the display, camera, battery, and casings of a smartphone adds up to material costs of around USD 45,[66] and associated treatment costs, including collection, transport, screening, executing the refurbishing process, marketing the refurbished product, and other administrative costs would add another USD 45. That said, in the current market a refurbished phone may still yield a profit of up to USD 100.

There are a few barriers, however, that could prevent smartphone refurbishment from scaling beyond a niche operation in the current market environment. One of the primary barriers is the difficulty third-party players would face obtaining smartphone components at market prices, given that the market is controlled by a small number of players. Together with the fact that refurbished smartphones typically have lower margins than new ones, this presents a significant obstacle to ramping up circular activities.

What, then, could be done to tap smartphone refurbishment potential?

Changing product design and improving treatment technologies could greatly improve the business case for circular smartphones, according to our interviews with industry experts. Useful design changes would include: reducing the use of adhesives and increasing modularity of components, using higher-quality materials to increase the robustness of plastic casings, and some technical tweaks to the circuit boards within smartphones that would reduce the likelihood of defects.[67] Separately, the inclusion of fault-tracking software—that is, software systems that identify which parts of

64 Credit Suisse, 'Smartphone report', broker report, August 2009

65 Gartner statistics on mobile device sales, September 2010

66 Based on average material bills of seven different products—Credit Suisse, 'Smartphone report', broker report, August 2009

67 Specifically, industry sources cite the need to increase the space between printed circuit board tracks as an important design change

3. How it works up close
Continued

a broken phone need to be replaced—would greatly facilitate the process of sorting used phones, which would improve the business case for circularity.

Establishing incentives to boost the collection rate of smartphones, for both B2B and B2C collection, would improve the scale and thus the economics of refurbishing operations. Such incentives might include buy-back systems for corporate customers, based on either a cash payment or credit towards a new purchase, offered to customers who return their phones at the end of life. Additionally, standardised software that fully wipes data from a smartphone would help overcome an important psychological barrier—users' fears that their data on a returned phone could be abused.

Implementing these changes could reduce treatment costs for refurbished smartphones by as much as 30%, making circular business models significantly more attractive. The resulting economic impact of an enlarged market for refurbished smartphones could be considerable. In a transition scenario in which collection rates are increased to 50%, and in which 60% of collected devices are ultimately refurbished, overall material input cost savings in the European B2B smartphone market[68] could amount to more than EUR 350 million per year. Such a system would also save an estimated 100 thousand tonnes of CO_2e emissions (measured in the linear supply chain) and would reduce manufacturing energy costs by USD 4 million. In a more advanced scenario (95% collection, 50% refurbishment, and 50% recycling), in which manufacturers and vendors cooperated to establish joint reverse supply chains, intra-firm incentive structures were fully aligned, and regulation was adjusted to enforce higher collection rates, net material cost savings would add up to more than USD 550 million annually in Europe, or 13% of the total amount the smartphone industry spends on inputs.

Such an advanced scenario would also allay manufacturer concerns that circular business practices would diminish profits from traditional production. In a diverse market with strong growth, the refurbishment of smartphones could enable manufacturers to tap new customer and geographic segments while earning a solid profit margin. Refurbishment of smartphones would also contribute to reducing input price volatility and the need to pay for hedging.

Light commercial vehicles—Getting extra mileage out of your material

Amongst the selected industries with medium-complexity and medium-lifetime products, by far the largest is the automotive sector, with global yearly sales of USD 1,880 billion.[69] Light commercial vehicles account for USD 240 billion of the total annual market for vehicles on the road.

For our business case and the subsequent calculations, we consider a representative light commercial vehicle with an average lifetime of roughly eight years in the European Union. In this period, the van goes through three distinct usage stages. New vehicles ex-factory are typically used for three to four years by customers that depend on high-quality, reliable transport. Average mileages during this stage of intense usage (e.g., as a delivery truck for postal and courier companies) are assumed to be 100,000 km p.a. In a second stage, vehicles change ownership when ageing and wear and tear increase the cost of maintenance as well as the likelihood of failures and downtime. Typical usage profiles include ownership by small to medium enterprises that use the van to haul products between depots and construction sites at a lower frequency. Average mileage in this phase is assumed to be around 50,000 km p.a. After this second stage, lasting four to five years, the van enters a third active usage period across the EU's eastern borders or in Africa, goes to recycling, or is stored as a source of spare parts.

Looking at the technical and economic break points, only a minor fraction of components is responsible for the degradation in van performance. From a circular economy perspective, the question arises whether exchanging these components could extend overall the life of the vehicle or at least increase its productivity—which is why we modelled a scenario in which OEMs adopt refurbishment activities at scale. Conservatively considering current technical

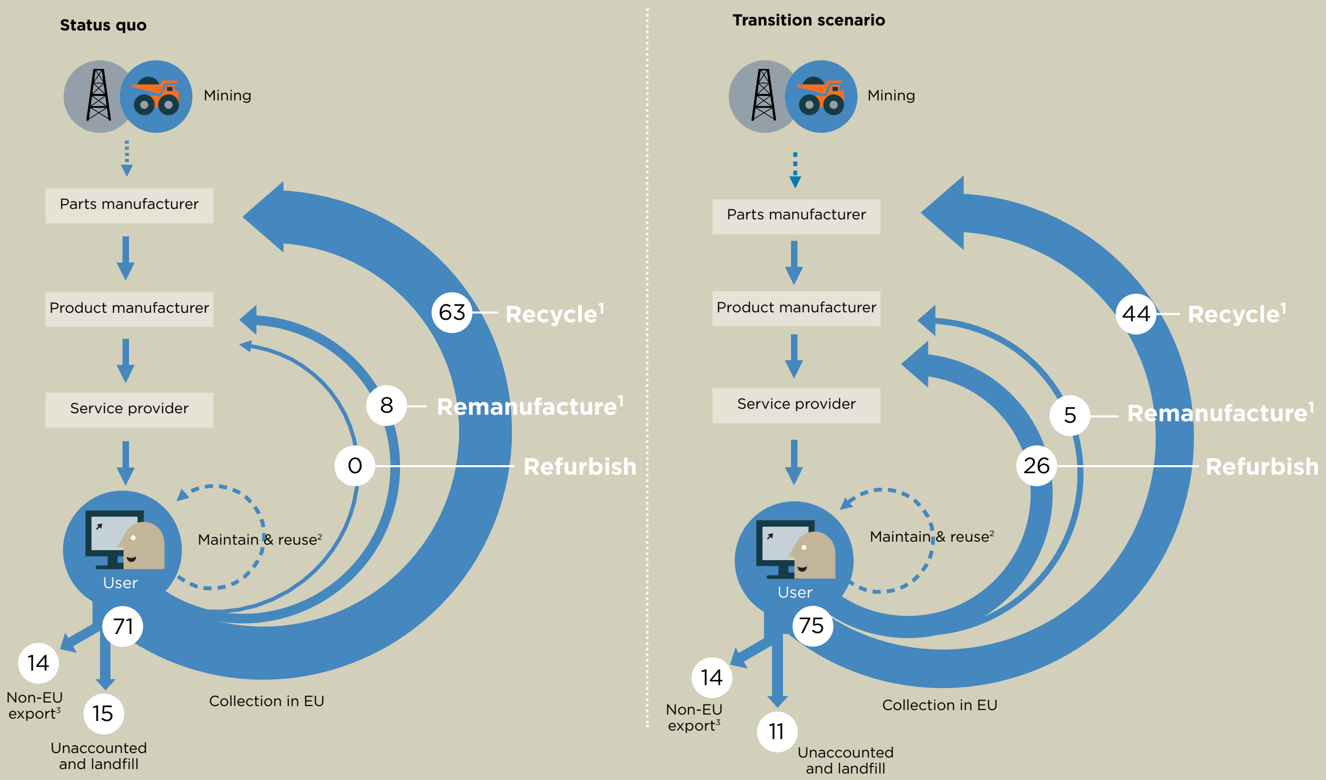
68 Total end-of-life enterprise smartphones in Europe estimated to be 13.4 million devices in 2010—based on Gartner statistics on mobile device retirements, September 2010; Yankee smartphone statistics, 2011

69 Contains major light vehicle OEMs, major medium and heavy commercial vehicle OEMs, and major suppliers in the automotive industry (Source: TCP, CLEPA, Annual reports, Automotive World Truck Report, McKinsey analysis)

FIGURE 12A
Light commercial vehicles: Refurbishment—a profitable alternative

ESTIMATES

End-of-life material flows based on 2008 EU figures
Percentage of total end-of-life vehicle weight



1 Today, recycling and remanufacturing take place in single treatment process as spare parts are taken from end-of-life vehicles (split here for better visibility)
2 Analysis focuses on end-of-life products (post de-registration), frequent resales of light commercial vehicles during intra-EU lifespan are not considered due to lack of data
3 Light commercial vehicles exported from EU with unknown intended usage or treatment
SOURCE: Eurostat; ANFAC; Öko-Institut; EIU; Ellen MacArthur Foundation circular economy team

feasibility alone, we derived two levers to move the status quo towards more circularity:

Improving vehicle design and focusing on exchanging the 'weakest link' components, which wear out or are most likely to break first, allows for a second usage period at full performance (i.e., 100,000 km p.a.). In our example, six components are exchanged: the engine and suspension, bumpers, wheels, battery, and fluids. Design changes enable easier, faster, and less expensive replacement of these critical components, e.g., modularisation of the engine by changing the design to bracket mounting, widening the engine bay for easier access to connection points, and using quick fasteners instead of screw couplings or bolted connections.

Establishing professional refurbishing systems to capture economies of scale in the reverse supply chain—by investing in proper tooling and achieving higher labour efficiency through process standardisation, workflow optimisation, and specialisation. Such refurbishing centres would typically be located centrally within the OEM's dealership and service network.

Although collection rates[70] of vehicles at the end of their final usage period (deregistration) are already as high as ~71%,[71] partially due to stringent EU directives, shifting volumes from recycling to refurbishing—as outlined in the transition scenario[72]—can still save substantial material inputs by roughly USD 8.8 billion (i.e., 15% of material budget) annually (Figure 12A).

70 The collection rate is defined as the percentage of total end-of-life LCV volume (in terms of weight) that is recovered through refurbishing, remanufacturing or recycling. Exports to non-EU countries, landfill, and other non-accounted disposal are counted as not collected

71 Georg Mehlhart et al., European second-hand car market analysis, Öko-Institut working paper, February 2011; Eurostat, ELV waste database, 2011

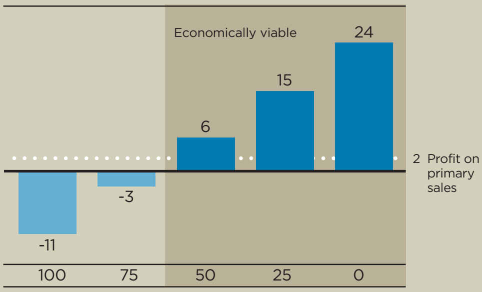
72 In this scenario, 26% of total end-of-life vehicle weight is recovered by refurbishment, 5% by remanufacturing, and 44% by recycling. This implies that 30% of collected vehicles are refurbished. The discrepancy between rates as a percentage of total end-of-life weight and as a percentage of number of end-of-life vehicles stems from the fact that is it not possible to recover 100% of a vehicle's weight through recycling or remanufacturing

3. How it works up close
Continued

FIGURE 12B ESTIMATES

Light commercial vehicles: Refurbishment is attractive for a large range of cases despite demand substitution of 50%

Net benefit[1] from light commercial vehicle refurbishment, considering demand substitution effects[2]
USD thousand per vehicle



Discount on refurbished vehicle[3]
Percent of new vehicle's sales price

1 Net benefit from 1st refurbishment: price of refurbished vehicle minus reverse treatment costs
2 Demand substitution rate assumed at 50%, it refers to the percentage of refurbished vans that replace the sale of a new van; cost of demand substitution is the profit margin on primary product sale
3 Original sales price of selected light commercial vehicle is approx. USD 41,000; OEM profit margin approx. 4%

SOURCE: Eurostat; ANFAC; Öko-Institut; EIU; Ellen MacArthur Foundation circular economy team

In addition, this will save about USD 192 million in energy costs as well as reduce the greenhouse gas emissions of the linear supply chain by around 6.3 million tonnes. Such a scenario could be developed more aggressively by increasing the share of vehicles collected for refurbishment to 50% of total end-of-life vehicles.[73] On an annual basis, a total of over USD 16 billion of net material, labour, and energy savings could be achieved in Europe alone.

While this is a considerable economic saving from a macroeconomic perspective, the question remains whether the individual company could or should have an interest in pursuing this potential. Demand substitution of new production—by discounted remanufactured parts and high-quality refurbished vans—is a concern that is understandably expressed in the industry. This point is especially acute as market forecasts for light commercial vehicles indicate that, at least until 2015, sales will only increase moderately.[74] A sensitivity analysis showing the impact of different discount and demand substitution rate combinations shows that, for light commercial vehicles, one could maintain similar or even achieve higher profit contributions from refurbished vehicles as compared with original sales of new vehicles (Figure 12B). This positive perspective suggests that companies have an arbitrage opportunity on refurbishment—if managed well. By marketing this new feature to customers and sharing the savings with users through reduced prices, they could also sharpen their competitive edge. OEM and sector-level initiatives to foster engineering education and R&D activities specific to circular production could further support wider adoption of such circular business practices.

Washing machines—Shifting ownership to achieve more cycles

In Europe, more households own washing machines than cars.[75] While washing machines are far more standardised than cars in both their physical dimensions and the amount of material they contain (typically 30 to 40 kg of steel per machine), they vary substantially in price and lifetime. Customer segments range from the single-person household needing 110 washing cycles a year, to hotels and laundromats, which commonly run their machines for 1,500 to 3,000 cycles a year. When contemplating a purchase, customers have a wide range of choices among models and performance.

Although all washing machines have similar components, their longevity measured in washing cycles ranges from about 2,000 for entry-level machines[76] to 10,000 for high-quality machines. The common break points are also well known: the motor, the pump, and the plumbing.

An economic opportunity with benefits for the material balance. The industry average for domestic washing machines is 250 cycles a year.[77] Given that warranty periods are typically not more than one to two years, average users frequently have an incentive to buy the lowest-cost machine and get, on average, 2,000 washing cycles. With usage periods of less than 10 years in mind, customer groups with low usage intensity are inclined to opt for lower-quality machines. Yet, over the long term, high-end machines cost users roughly 12 cents per washing cycle, while

73 In this scenario, 43% of total end-of-life vehicle weight is recovered by refurbishment, 4% by remanufacturing, and 32% by recycling. The difference between rates as a percentage of end-of-life weight and as a percentage of end-of-life vehicles is explained in the previous footnote

74 HIS Global Insight, Light commercial vehicles sales in Europe, September 2011

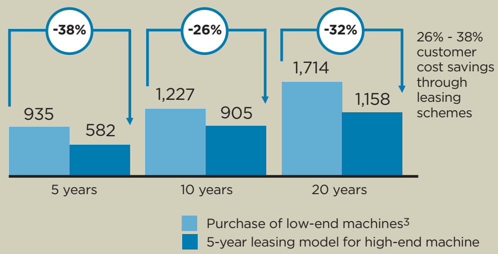
75 Euromonitor washing machine statistics, 2011; Statistisches Bundesamt, car statistics, 2009

76 A sub-segment of entry-level machines is built for only 800 to 1,000 washing cycles

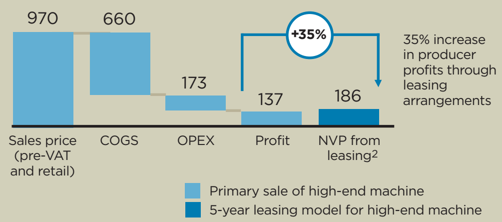
77 Ina Rüdenauer et al. , 'Eco-Efficiency Analysis of Washing Machines', Öko-Institut working paper, November 2005; Rainer Stamminger et al., 'Old Washing Machines Wash Less Efficiently and Consume More Resources', Hauswirtschaft und Wissenschaft, 2005, Vol. 3; expert interviews

FIGURE 13
Washing machines: Leasing durable machines can be beneficial for both parties

Customer's net present costs[1] of washing machine usage over time[2]
USD per customer



High-end machine manufacturer's profits from primary sale and leasing
USD per machine



1 Here, net present cost is the sum of a customer's discounted cash outflows for washing machine purchases over a specific time horizon (5, 10, and 20 years)
2 Applied 8% discount rate
3 Low-end washing machines with a lifetime of 2,000 cycles and cost around USD 540

SOURCE: Company information; Öko-Institut; Sundin (2004); UNU (2008); Stamminger et al. (2005); Ellen MacArthur Foundation circular economy team

low-end machines cost 27 cents per cycle. We can also show that the costs incurred by an average household using one high-end machine over a 20-year period are lower than if the same household uses a series of low-end machines to do the same number of washes over the same period.[78]

The trade-offs between high- and low-quality machines also have implications for material and energy consumption. Given similar material compositions and production processes, replacing five 2,000 cycle machines with one 10,000 cycle machine yields almost 180 kg of steel savings and more than 2.5 tonnes of CO_2e savings. These carbon emission savings could be partially offset by missed energy efficiency improvements that would have been more readily available if the household bought a new machine more often. It is therefore important that such gains—which are largely driven by optimising temperature, spin rate, and washing time—are also accessible to users of 'built-to-last' machines. Luckily, energy efficiency-enhancing features such as wider ranges of programmes, automatic load detection, sensor technologies, and auto dosing systems are usually a matter of software, electronics, and sensor systems—components that could be reintegrated into machines post production without substantially changing their structure.[79] Providing updating and upgrading washing machine programmes after the first sale can thus be a way to offer energy efficiency improvements without regularly replacing the whole machine.

Changing the business model to gain against the low-cost segment. To realise the positive economic and ecological implications of durable washing machines, OEMs could consider offering high-end washing machines in a usage- or performance-based model. This could enable average users to profit from low per-cycle costs of high-end machines within a shorter period of time. A five-year leasing agreement would remove the high upfront cost barrier for customers and distribute costs over a defined period of time.

In a scenario where a 10,000-cycle machine worth USD 970 (before VAT and retail margin) is leased over a five-year period (11% interest rate) by a family (500 cycles p.a.), both the customer and the manufacturer could improve their economic situation.[80] Over the implied lifetime of 20 years, the machine could be leased four consecutive times with a certain degree of reconditioning in-between (reflected in reconditioning costs of USD 105 after every lease, which include transportation costs, quality checks, cleaning and cosmetic changes, as well as software and systems upgrades).[81] Independent of the time horizon (5, 10 or 20 years), the value that both the user and the manufacturer derive from the deal is higher than what they would get from a conventional sale (Figure 13).

In a way, such leasing contracts remove inefficiencies in the market that stem from a maturity mismatch between the typical time horizon a household has when buying

78 To perform this analysis we calculated a net present value (NPV) for high-end versus low-cost machine purchases (the 20-year NPV for a family using 500 cycles per year is USD -1,714 when purchasing a low-cost machine versus USD -1,158 when buying a high-end product). In this context the net present value is the sum of a customer's discounted (8% discount rate) cash outflows for washing machine purchases over a specific time horizon

79 Ina Rüdenauer and Carl-Otto Gensch, Einsparpotenziale durch automatische Dosierung bei Waschmaschinen,Öko-Institut working paper, June 2008; Ina Rüdenauer and Rainer Grießhammer, PROSA Waschmaschinen, Öko-Institut working paper, June 2004; Panasonic company website; Samsung company website

80 This also holds when a third party (e.g., bank) acts as an intermediary and charges an additional 100-200 basis points. How the economic improvement potential is divided between manufacturer, customer, and a potential third party eventually depends on the individual contract and existing market dynamics (e.g., purchasing power or competition)

81 Underlying machine prices for leasing contracts refer to product value at given points in time under linear depreciation over expected lifetime of 20 years (=10,000 cycles)

3. How it works up close
Continued

a machine and the time horizon high-quality machines are built for. The leasing scheme transforms a long-term investment in a 10,000-cycle machine into multiple cash flows and the right to use the machine for a certain period of time. This results in an economic win-win situation and yields positive material and energy implications through prolonged lifetimes of the products.

Combining benefits of new business models with effective refurbishment. As leasing models give manufacturers strong control over products over the life cycle and result in high and stable product return rates, they facilitate the recovery of value embedded in those collected products. End-of-life washing machines are typically recycled, yet it is estimated that only up to 10% of collected[82] machines currently get refurbished.[83] In many cases, old washing machines are intact and would be reusable following the replacement of some components (e.g., motor, bearings, front panel, printed circuit board, or pump) and some cosmetic changes. The cost for collection, transport, the refurbishing process, and other expenses is currently estimated to be around USD 170 per machine.[84] The material cost of replaced components could amount to as much as USD 300, but depends on the machine's quality segment as well as the number of replaced parts. This could make refurbishment economically viable in some but not all cases.

Combining new leasing models with refurbishing activities can be a particularly interesting opportunity. In a situation where circular activities would be pooled and replacement parts prices would not be subject to the high trade margins currently observed, material costs in the refurbishment process could be reduced by up to 40%. This would make refurbishment more attractive and foster the idea of (multiple) leasing systems for high-end but also other kinds of washing machines, as their lifetimes increase with effective circular treatment.

A comparison of costs for new and refurbished machines indicates that material input costs per product could be reduced by up to 60%, net. From an industry perspective, a transition scenario in which the collection rate increases from 40% to 65% due to adoption of new leasing models, and 50% of collected machines get refurbished (and the other half gets recycled) would generate net material cost savings of more than 12% of total industry input costs. In an advanced scenario, alternative ownership models, such as leasing or performance-based arrangements, could be brought to higher scale with specialised intermediaries entering the market. Aligning incentives between customers and manufacturers regarding contract financing and duration is essential to make alternative ownership models work. In an advanced scenario with proliferation of alternative business models, an increase in manufacturer control over machines in circulation could be reflected in collection rates of up to 95%. This could be further supported by collaborative collection and treatment systems, which would improve the entire reverse supply chain. In such a scenario, the net material cost savings associated with refurbishment and recycling could be around 18% of total industry input costs.

Shift to performance-based contracts already happening. Many ideas have already been put forward to exploit the economic and business opportunities outlined above.

Pay-per-wash model. In Northern Europe, Electrolux offered customers per-wash options based on smart metering. The manufacturer installed its high-quality washing machines in customer homes, connected to a dedicated measuring device installed at the power outlet. This enabled tracking of not only the number of washing cycles but also the programme (e.g., cold versus hot wash). This business model was discontinued after the utility provider discontinued the smart metering. Without this element, Electrolux was unable to assess customer-specific usage and charge the customer accordingly. Further, customer acceptance was rather low; the advantages (e.g., free servicing, easy trade-in for upgrades, high-end machines with hardly any upfront costs) were not marketed adequately.[85]

Refurbishing model. ISE, a specialty washing machine company producing professional washing machines (10,000 to 12,000 cycles) in sizes comparable with domestic models, collects used heavy-duty washing machines from hotel or laundromat customers. After

82 In Europe, ~40% of large domestic appliances are collected in official WEEE channels. It is estimated that much more than that is collected via 'unofficial' channels. Source: Eurostat, WEEE key statistics and data, 2011; CECED, Joint position paper on WEEE recast second reading, CECED position paper, July 2011

83 Jaco Huisman et al., 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment – Final Report, United Nations University working paper, August 2007; Adrian Chapman et al., Remanufacturing in the U.K. – A snapshot of the U.K. remanufacturing industry; Centre for Remanufacturing & Reuse report, August 2010

84 This is in line with the assumed cost for reconditioning in the leasing process

85 David Pringle, 'Electrolux offers free washers to homes that get wired', Wall Street Journal Europe, February 2000; Timothy C. McAloone and Mogens Myrup Andreasen, Design for utility, sustainability and societal virtues: developing product service systems, International Design Conference working paper, 2004; Jacquelyn A. Ottman et al., 'Green market myopia', Environment, 2006, Vol. 48 (5) refurbishment, it sells these machines to the domestic market at a discount price.

Lease model. Several market participants have discovered the potential of offering leasing contracts for washing machines to commercial users as well as to private households. Specialty leasing providers such as Appliance Warehouse of America offer a wide range of products and contract specifications to meet customer demands. Home appliance manufacturers such as Bosch Siemens Hausgeräte provide leasing to customers under a 'full service' scheme, which includes warranties that cover the whole contract time frame.[86] This provides the customer not only with increased flexibility in terms of timing but also with better service levels and added convenience. In such a setting, third-party financing companies may take up an intermediary role, matching manufacturer and customer incentives and handling administrative tasks.

All of these already existing models have illustrated potential for increasing material productivity. When explaining why these models would not work, manufacturers typically cite the following concerns:

Total cost of ownership (TCO) will increase. Current washing machine manufacturers cite the potential problem that customers would be unable to participate in the continuous efficiency gains in energy or water consumption offered by new washing machines. Therefore, a long-lasting model could be less attractive from a TCO perspective. This concern would be highly problematic—were it not for the potential of leasing models. As we have shown in our net-present-value analysis, both washing machine sellers and customers can benefit from a model in which long-lasting machines are leased to customers—who then have the option of upgrading to a different lease model if a more efficient model emerges. Furthermore, efficiency gains often stem from innovation in the washing programme software or sensor systems, which can be easily upgraded. Doing this would provide a quick fix through which leasing firms and customers could inexpensively participate in these continuous efficiency gains.

Longer-lasting machines will substitute for new models and decrease sales. As with any transformative technological change, a shift toward a circular economy would have winners and losers. It may well be that manufacturers of inexpensive washing machines, with high per-wash costs to consumers, would have to adjust to competing offerings of longer-lasting, more efficient models in a circular economy. That said, it should not be discounted that such 'creative destruction' also creates new opportunities—for instance, refurbishing and selling replacement parts for washing machines, or participating in the various aspects of the service industry that would be needed to support a circular washing machine business model.

Customers will not accept new, alternative contract schemes. Some manufacturers argue that customers are used to purchasing household goods rather than leasing or renting them. Customers may avoid leasing contracts due to uncertainty and insecurity about financing agreements. While this may be true in the near term, there are myriad examples of users shifting to different ownership models. One case in point is the industry for short-term, inter-city car rentals, which has proven to be a resilient model that has enabled consumers to scale back car purchases in favour of less expensive and more convenient short-term rentals. Furthermore, transparency with regard to contract conditions and effective marketing of customer benefits (e.g., quality machines with hardly any upfront costs and easy collection) would help remove such concerns.

The financing of upfront production costs poses a financial risk to manufacturers. In a leasing scheme, the producer faces a maturity mismatch between upfront production costs and future cash flow streams. Financing this gap from the company's own funds could be a financing risk to a certain extent, yet typically these risks can be carried by financial intermediaries.

86 Company website (http://www.bosch-home.com/de/produkte.html)

3. How it works up close
Continued

The end of Electrolux's experiment with its new leasing business model shows that challenges may arise in the cooperation with business partners, which can hinder a new business model from becoming effective and profitable. Adopting more circular business models will therefore require skills in new forms of collaboration and alliance-building—but this, too, we see as eminently feasible, and indeed quite lucrative given the potential rewards.

Power tools—Power by the hour

Like mobile phones, power tools are currently only recycled to a small extent as end-of-life products and rarely remanufactured for reuse. Yet many used power tools contain electrical components that are very durable and not subject to changes in technology or fashion, thus offering significant value recovery potential. B&Q, the U.K. home improvement company, estimates that even today 20% of collected power tools could be refurbished. Given the recoverable value and current costs of treatment, refurbishment of power tools makes sense only for mid-range/high-end products. As power tools are somewhat sensitive to humidity, more products could be refurbished if they were appropriately stored during their usage phase and during the reverse logistics process.

A scale-up to significant levels of refurbishment and adoption of new business models would need to proceed along the following lines:

Implement in-store collection, testing processes, and alternative circular business practices for power tools. End-of-life collection points could be set up in every store for a per-store investment of ~USD 1,500, and labour costs could be kept to a minimum. As an alternative to third-party collection and recycling, end-of-life products could then be transferred back to the store's distribution centres, where testing facilities would check for reusability of products and components. Some of the products could then be refurbished or remanufactured in internal or external facilities. The key success factors of the approach are cost-efficient reverse logistics (e.g., dry storage and making use of returned, empty distribution vehicles) and product designs that increase durability and facilitate the process of disassembly and refurbishment (e.g., specifying a robust case made from impact-resistant polymers and carefully placed protective rubber inserts, vibration resistant connectors, and high-quality copper motor windings).

Adopt new business models and a segmented approach to circular activities. One new business opportunity could be rental and leasing schemes for high-end power tools. As these products are durable and are typically used only sporadically and for a defined period of time in the household segment, high-quality power tools could be hired out several times and repaired and refurbished at defined intervals between hires. As part of a service contract, a company could also create additional customer value by offering training, workshops, and other kinds of useful do-it-yourself information, which serves a marketing purpose and also functions to highlight the increased value of durable products to customers. In a more comprehensive service offering, companies could provide kits with all the equipment needed for a specific project (e.g., constructing a new kitchen). This would mark a switch from a product to a service or system business, in which the power tool manufacturer hires out relevant tools and collects them at the end of the project, during which the manufacturer sells consumables (e.g., screws, nails) and other higher margin items as part of their 'kitchen renovation kit' (e.g., paints, fixtures). This would increase efficient use of the products and enhance overall lifetimes through frequent repair and refurbishment. When combined with additional customer services (such as support in project planning, selection of required equipment and materials), a contract scheme of this sort could generate significantly more value for customers than standard product purchases.

Short-lived products and consumables — The opportunity for biological nutrients

Short-lived products and consumables represent roughly another third of Europe's manufacturing sector. Products such as textiles may have only a short usage period and products such as food and other agricultural products (e.g., paper) are often consumed within days to months of initial production. For this type of product, the most effective steps towards a more circular economy are likely to move away from technical nutrients to biologically based loops in order to make these products serve a restorative purpose, rather than an exploitive one. Similarly, other steps focus on improving their usage periods or, at a minimum, switching to cascading usages. In the following analysis, we look at food and textiles:

- Food is an important segment in the consumables category. It is a major contributor to current waste streams, yet holds significant economic potential in being safely reintroduced into the biosphere to rebuild natural capital after energy and specific nutrients have been extracted on the reverse loop.

- Textiles offer a showcase of how a product/material can cascade through multiple uses in different value chains and achieve substantial material savings by consecutively replacing other virgin material needs.

Food—Multi-vitamins for the earth

Biological nutrients, after consumption—and often even before consumption—become waste. In Europe today this waste is largely discarded, as sewage through our flush toilet-based sewerage systems, or as an organic fraction in the municipal and industrial solid waste streams. Only limited amounts of what gets collected is ultimately composted, anaerobically digested, or reused.

At the same time, ever more soils are depleted of nutrients as we seek to nourish a growing population with a changing and increasingly land-intense diet. Currently, this leakage is compensated for with mineral fertilisers that are energy-intensive to produce—and sometimes geo-politically challenging to procure. The U.S., for instance, have stopped all export of phosphate rock (a critical ingredient in fertiliser under the current system) and China has raised its tariffs on the same—a problematic development since, together with Morocco/Western Sahara, these countries were responsible for 67% of all the rock phosphate output on the market in 2009.[87]

In what ways, then, would a circular economy differ? First it would seek to avoid losses in the value chain such as the 'loss' of land through low yields, loss of food volumes and/or spoilage caused by distance to market and inadequate cold chains. The need to avoid food waste both at the point of sale with the retailer and within households is gathering momentum amongst corporate and political decision makers—as evidenced by voluntary initiatives such as the Courtauld Commitment in the U.K. and various initiatives originating at the European Commission. Motivations can be grouped along three lines: compliance with the European directive on increasingly keeping organic waste out of landfill, questions around social justice and access to food, and—in a more complex and indirect way—the necessity to cut down on such waste if we want our agricultural supply chains to keep up with nutritional needs.

The circular economy would avoid landfilling and would try to extract the maximum value from agricultural materials. It would inject valuable biological nutrients into a truly circular path consisting of material reuse (e.g., the reuse of wood in oriented strand board or particle board), extraction of biochemicals and commodity feedstocks (e.g., specialty chemicals from orange peels), extraction of nutrients and soil improvers (through composting and anaerobic digestion), and extraction of energy (through anaerobic digestion and other waste-to-energy technologies)—in other words 'optimal biomass valorisation' (Figure 14).[88]

In the U.K., the annual amount spent on landfilling would fall by USD 1.1 billion if the food fraction that is now in the municipal

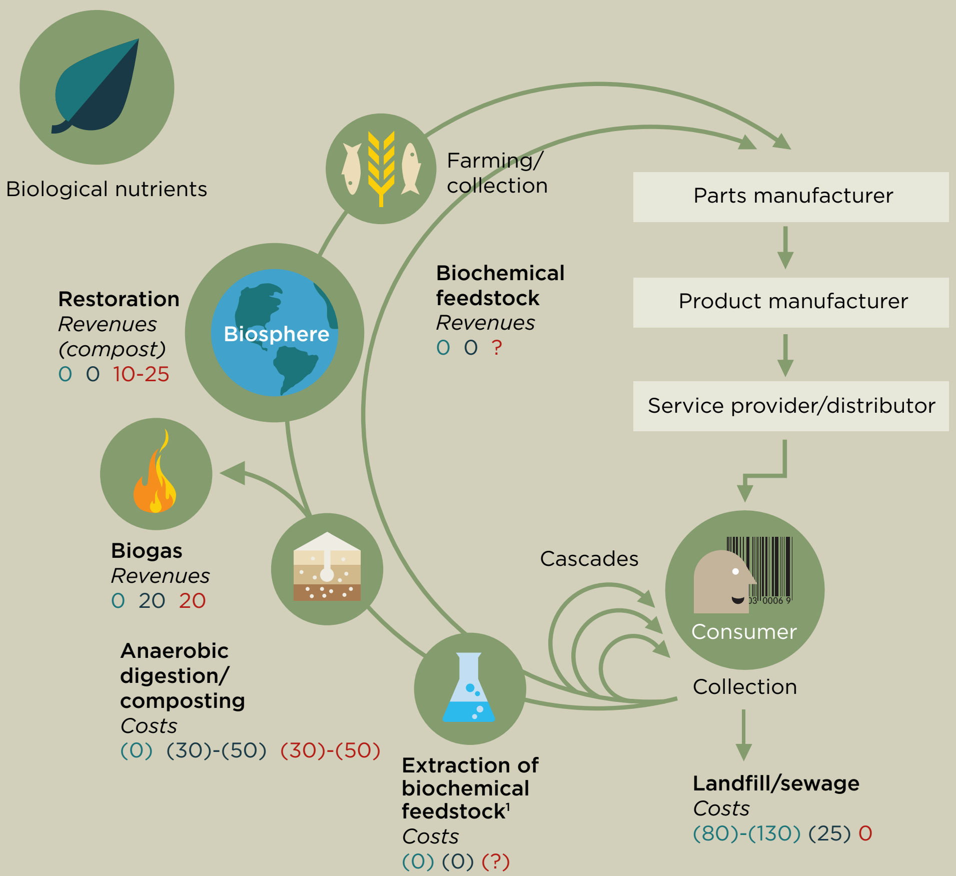
87 A rock and a hard place: Peak phosphorus and the threat to our food security, Soil Association, p. 2

88 L. Asveld, R. van Est, D. Stemerding (eds): Getting to the core of the bio-economy: a perspective on the sustainable promise of biomass; Rathenau Instituut September 2011

3. How it works up close
Continued

FIGURE 14
Biological nutrients: Diverting organics from the landfill to create more value

EUR/tonne collected—negative numbers indicate a cost



	Status quo	*Transition scenario*	*Advanced scenario*
Total cost	(80) - (130)	(55) - (75)	< (30) - (50)
Total revenue	0	20	> 30 - 45
Total net gain	(80) - (130)	(35) - (55)	- (0) - ?

1 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

solid waste were diverted to more useful purposes such as compost and energy. In addition, the externalities of landfilling such as its impact on land use—including the societal burden associated with siting choices—and greenhouse gas emissions would be greatly reduced. For example, up to 7.4 million tonnes of CO_2e would be avoided by keeping organics out of landfill. Beyond landfill avoidance, the benefits of maintaining biological nutrients within a circular economy are manifold, from the provision of specialty and commodity chemicals to land restoration and energy provision:

Feedstock provision. Full 'valorisation' means that we try to extract the maximum value from biomass waste before it is used for energy or soil restoration purposes. In its most sophisticated form, valorisation happens at a so-called bio-refinery where—with the help of enzymes and bacteria—biomass is turned into a full range of fibres, sugars, and proteins, and later plastics, medicines, and fuels. Individual refining processes are already being applied successfully at commercial scale, but only in few instances have such processes been combined into a full refinery operation. Processum Biorefinery Initiative in Sweden is one of the few organisations producing a full suite of biochemicals—in their case from forest biomass. The extraction of specialty chemicals typically only cuts volumes down by 1 to 2 % and the remaining biomass, which is rich in carbon, can subsequently be turned into commodity chemicals such as bio-polyethylene. While some large chemicals players like Dow have entered the biopolymers market, the market at present is mostly driven by players in the biomass cultivation and user industries, such as consumer goods manufacturers. Because of the large range of input materials, processes, and products, it is difficult to put an average number on the cost and net value of such production operations.

Land restoration. Here we are touching on one of the key characteristics of the circular economy—its ability to restore the land, promote soil fertility, and thus increase harvests. Alternative sources of nutrients (sewage, animal waste, and food waste) could be sufficient to cover the entire need for fertiliser in today's production systems and break the dependence on foreign minerals. Doing so, however, would require both technical innovation and changes in the legislative framework.

Rethinking agricultural production systems

In natural ecosystems, essential nutrients such as nitrogen and phosphorous return to the land after they have been absorbed by plants and digested by animals, maintaining a healthy balance. In today's agricultural production systems, however, it is common practice to remove most above-ground biomass from the land and to disrupt the animal-to-soil loop as well by keeping animals penned rather than letting them out to pasture. As a consequence, it has become necessary to sustain the yield of nutrient-depleted soils with mineral fertilisers—a practice that is affordable only so long as the energy to extract and process those minerals is cheap and the minerals remain available. Western Europe depends on imports for more than 80% of its phosphate requirements,[89] which is not without risk given the real limits to economically accessible phosphate rock reserves—one of the most important sources of mineral fertilisers—and the high concentration of those reserves in only a few countries, as discussed earlier.

89 Current World Fertilizer Trends and Outlook, Food and Agriculture Organization, 2008, p. 12

3. How it works up close
Continued

Let's take phosphorous from human excreta as an example. Urbanisation is increasing sludge produced through municipal wastewater treatment; regulation is requiring higher proportions of wastewater to be treated, further increasing sludge production; and sludge management represents up to 50% of total wastewater treatment costs (which then, in turn, are further exacerbated by high energy costs, which account for 25 to 30% of sludge management costs). While little operational data is available on the costs of recovering phosphorus from sewage treatment plants, academic literature puts the cost at an estimated 2 to 8 times that of mined rock.[90] Such high costs may make sludge extraction an unlikely candidate to compete with mined phosphate rock, but in 2008 the price of the latter flared up even beyond this point. Since then, prices have dropped to a quarter of the high, but 2011 saw over a 30% increase in rock phosphate prices, from a monthly average of USD 155/tonne in January to USD 203.50/tonne in December[91]—making the prospect of profitable sewage nutrient recovery suddenly much more realistic.[92] Until that moment comes—or until technological development and scale bring down costs—businesses such as Ostara Nutrient Recovery Technologies are building their business model mainly on the overall cost reductions for water treatment plants by reducing maintenance requirements. On the other hand, a number of low-tech developments on the market cut out the sludge phase altogether by separating urine from faeces, ranging from the PeePoo bag that enables villagers to use their excrement straight as a fertiliser to separating toilets that allow infrastructure clusters to develop small-scale nutrient concentration solutions.

Energy provision. Energy can be extracted from food waste in several different ways, with anaerobic digestion (AD) and incineration being the most common ones. Given food waste's high moisture content, AD will in many cases deliver superior value. In the U.K., for example, the food waste currently contained in the municipal solid waste stream could deliver up to 1,960 GWh of energy through AD. And that is food waste only; the available volumes of animal waste—which is also well suited for digestion—are more than 10 times as big. At the moment, however, the U.K. AD infrastructure remains largely undeveloped. That may change soon. The Scottish government, for example, intends to lead the way and has laid out in one of its policy papers the significance AD could hold for Scotland in terms of energy and soil restoration. Also in the U.K., National Grid has taken an active interest in developing biogas, from food and other sources, as an alternative to natural gas for heating purposes. Because many biogas providers are sub-scale, tapping into this source at scale will require a few changes at the system level, for example by relaxing quality control rules, which were developed for activities in gas terminals, and by adjusting the commercial rules, which are better suited for the oil majors for which they were designed.

Textiles—Dressing up for different occasions

Textiles, whether made of biological or technical nutrients, offer a terrific example of the cascading opportunity. This is particularly important for apparel, the usage of which is often largely determined by fashion rather than technical lifetime limitations. Instead of disposal in the landfill after first use (where they generate up to 3.6 million tonnes of CO_2e in the U.K.[93]), textiles can be reused multiple times. Reuse of apparel in good condition offers the lowest costs and biggest savings. Various models exist, from donations and clothes swaps to small- and large-scale commercial resale operations (e.g., Patagonia's Common Threads Initiative).

When no longer suitable for its originally intended purpose, the next loop for clothing can be re-yarning of treated fibres, with some reduced costs and savings on externalities. End-of-life apparel can also be used as stuffing in upholstered furniture, car seating, mattresses, and heat and sound insulation (as illustrated in Figure 9). Some of these applications, too, can be repeated a few times. We modelled the effects of cotton textiles being transformed into furniture stuffing, and then reused again as housing insulation. For synthetic fibres there is also the option of de- and repolymerisation into new fibre applications. This process is, for example, applied by the Italian company Aquafil, which turns Desso's post-consumer carpet waste into new polymers and then

90 Water Environment Resource Foundation (www.werf.com)

91 IndexMundi, Commodity Price Indices (http://www.indexmundi.com)

92 World Bank (www.worldbank.org), Water Environment Resource Foundation (www.werf.com)

93 2006 IPCC Guidelines for National Greenhouse Gas Inventories, McKinsey analysis new yarns, and by Teijin in Japan, which turns apparel from Patagonia's post-consumer collection programme into new polyester fibres. Finally, after other options with more cost and resource savings have been exhausted or are no longer possible due to the quality of the fibre, the final loop for textiles could consist of energy recovery in various possible forms. We modelled anaerobic digestion, a technology that is appropriate for cellulose-based textiles such as cotton and viscose, with all the residue going to landfill.

These various transformations of cotton along the cascade allow for substitution of conventional input materials, the production of which may be energy intense or may require large amounts of water.[94] These include the polyurethane foam used as furniture stuffing, the stone wool typically used for building insulation, and the electricity production saved by creating energy through anaerobic digestion. Our analysis shows that this replacement process is certainly economically viable (the numbers depend strongly on the assumptions around technology innovation, but cumulative costs along this particular U.K. cascade could amount to about USD 120 million, while the products they save cost up to USD 315 million).[95] Furthermore, the cascade process saves CO_2e emissions and water usage associated with the production of the substituted products. Looking just at the U.K., we determined that these savings could add up to 1 million tonnes of CO_2e and 16 million cubic meters of water.

94 PlasticsEurope: Eco-profiles of the European Plastics Industry: Polyurethane Flexible Foam, Brussels, 2005

95 We analysed the cascade of cotton textiles transformed to furniture stuffing, then transformed to housing insulation, and finally anaerobically digested (with the resulting biogas converted into electricity and the digestion residue landfilled). Economic viability was assessed through comparison of wholesale price of conventional product with its reused cotton substitute. Cotton-derived products turned out to be highly competitive. For this comparison, adjustments due to differences in weight and insulation efficiency were applied. The base cotton volume entering the cascade is defined as 50% of today's recycled textiles. Here, further potential exists as the collection rate for textiles in the U.K. is low at 22% and recycling only accounts for 6% of collected volumes (Oakdene Hollins: Recycling of Low Grade Clothing Waste, September 2006; McKinsey analysis). For the following steps in the cascade, it was assumed that 50% of material enters the next cascading step

Other short-lived products and consumables

This category covers a broad range of products for which circular solutions may take on entirely different forms. For some short-lived products, it may be possible to change their properties or that of the system in which they function and, by doing so, to switch the delivery of their function into the durables or service systems categories. For many more, however, their short lives cannot be altered in an economically or functionally acceptable way. Many forms of packaging, for instance, belong to this group. Why, then, would we continue to serve these purposes through the consumption of technical nutrients—which are finite in nature and, at the end of their useful life, take up precious disposal capacity or visually pollute in the best case, and cause considerable damage to health and environment in the worst?

A better option may be to use materials that are biogenic in their origin, remain unadulterated by toxic chemicals at all stages of their lifecycle, and after consumption return to the biosystem—where they will restore systems that have been previously depleted of minerals and organic nutrients. Priorities here include moving short-lived products into pure bio loops, increasing agricultural productivity to reduce land-use conflicts, and providing the system for retrieving and treating bio-based materials as compost.

Moving short-lived products into purely biological circles can build on some existing foundations, for example, in packaging. Shortly after its introduction, cardboard took off as a mass packaging material. Today, despite the advent of numerous new packaging materials and technologies, board represents a third of the packaging market. Since the key raw materials are virgin and secondary fibre, packaging of this type should be inherently biodegradable and compostable. Numerous studies and pilot efforts have shown that this is the case, but growing performance demands on paper for both print and packaging applications have led to the use of an increasing number of additives, many of them toxic. When such toxic materials end up in compost, it is no longer possible to apply it widely as soil improvement: in many cases, its best use is as daily cover in a landfill. Here, too, a design system that had not taken into account the poor design outcomes for end-of-life treatment needs to be mended—the goal would be to flush toxic chemicals from the value chain as much as possible and find non-harmful substitutes that can deliver the same performance. The benefit of having healthy compost that is suitable for a broad range of applications is real and measurable.

We do not need to resolve the technical/biological nutrient switch with today's materials only. Many companies have taken on the challenge of providing bio-based materials that can rival conventional petroleum-derived products in terms of both

3. How it works up close
Continued

Harnessing innovation

Material and technological innovation is a core enabler for fast-tracking transformation from a linear into a circular economy. While many of the proposed alterations on the journey to a circular economy will be gradual, innovation could likely lead to a more disruptive and accelerated arrival. Also, while the analysis provided in this report is based on materials and processes known today, a focusing of innovative forces on the restorative circular economy model may lead to opportunities that are currently unknown to the economy.

Changing the efficiency of production processes, for instance, by moving towards 3D printing instead of milling, could dramatically reduce the production-induced waste of resources while enabling more flexible design and variations of produced components, for example, the specific fitting of missing spare parts to extend the life of a product such as a van, and hence drive down inventory and obsolescence risks.

The introduction of alternative materials could reduce input scarcity and potentially lower costs of material intake (e.g., substituting graphene for indium tin oxide in solar cells). Advances in biological materials (like self-healing mobile phone cases) or advances in chemistry (like non-toxic alternatives) could further accelerate the adoption of concepts of the circular economy. Changes in the durable, technical-component part of the product or product system could lead to a different usage of consumables. A significant part of a washing machine's total environmental impact, for example, arises from the discharge of soiled water and dissipation of detergent. While recent technological developments have so far mainly focused on minimising the use of detergents,[96] it is also conceivable to develop technologies (e.g., applying membrane technology) that allow for detergent recovery after consumption.[97]

This is the field of speculation, as advances are happening behind closed doors at leading R&D outfits. Yet there is certainly evidence that change is underway. Former Ecover CEO and ZERI creator Gunter Pauli, for instance, has compiled 100 innovations in his 'Blue Economy' initiative, several of which could also accelerate the migration towards a more circular economy.[98]

96 See for instance technologies developed by Xeros, a University of Leeds spin-off (http://www.xerosltd.com/nylon-polymer-technology.htm)

97 Tim Jackson, Material Concerns: Pollution, Profit and Quality of Life, London: Routledge Chapman & Hall, 1996

98 The Blue Economy is an open-source movement that brings together concrete case studies. These were compiled in an eponymous report describing '100 innovations which can create 100 million jobs within the next 10 years' that was handed over to the Club of Rome in 2010. As the official manifesto states, 'using the resources available in cascading systems, (...) the waste of one product becomes the input to create a new cash flow' functionality and cost. These companies range from leading chemicals manufacturers such as Dow (impact modifiers and process aids for polylactic acid or PLA) and BASF (Ecoflex) to niche players such as Cyberpac (Harmless Packaging) and the Canadian firm Solegear Bioplastics (compostable plastics).

Overcoming functional gaps will require a great deal of innovation on the part of chemicals and packaging companies, and at the universities and research institutes that provide these industries with new ideas and insights. As with the other challenges posed by the circular economy, here, too, appropriate curriculum changes are vital to create and impart knowledge in and across relevant disciplines, and researchers and companies alike will need to tap into many different sources in order to generate sufficient levels of innovation (see also sidebar). In the marketplace, arriving at scale will require buy-in from brand and volume leaders in the packaged goods industry so that demand will pick up quickly and prices can come down.

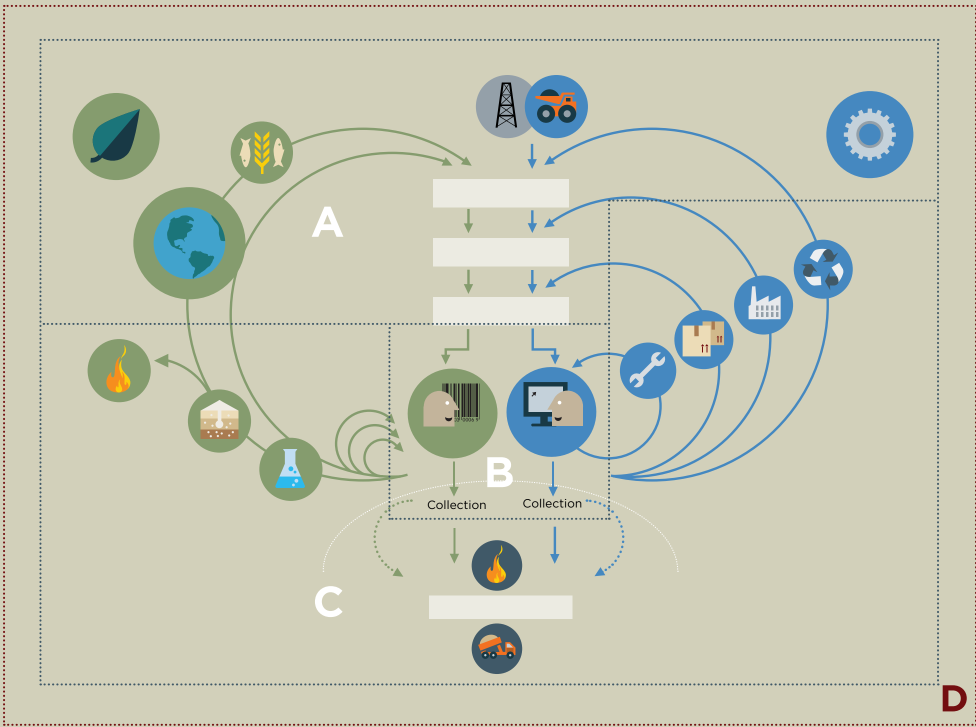
Growing a sufficient supply of biofeedstocks will require increases in agricultural productivity to help free up the amount of required arable land. In today's agricultural supply system, large-scale feedstock demand for biochemicals will compete for land with other biomass applications such as food, fibre, and fuel. Since biochemicals fetch a higher price than biofuels, they will likely compete successfully with the latter, but as the biofuels debate in recent years has shown, under today's circumstances even the existing relatively small biofuel feedstock volumes already raise important trade-off questions in terms of land requirements.

Policy makers, most likely in public-private-partnership constellations, need to stimulate end-of-life treatment systems that are suitable for the materials on the market—including biological and biochemical ones. The key is to provide the system. Examples include Seattle and San Francisco, both of which have not only set the rules for the choice of bio-nutrient-based materials for single-use fast-food packaging, but have also provided the municipal infrastructure to properly handle such waste. A more complex issue is that, with current high levels of landfilling, many inert bio-based materials end up adding to the production of landfill gas, so that more and more technology to capture landfill gas is required. If landfill diversion rates were to go up significantly, however, as is to be expected under EU legislation, bio-based materials such as coated and printed paper and cartonboard might negatively affect the quality of recyclate—unless high-performance sorting technologies are applied. Large-scale deployment of biological nutrients would therefore require systems that capture them and return them to the earth. In such a system, new biological nutrient applications such as packaging, when designed with suitably bio-based coatings and inks, can actually reinforce the existing composting/anaerobic digestion system. As conventional packaging materials are often a source of contamination in organic material, bio-based alternatives may ensure a lower level of contamination for organics and hence better commercial value for the compost/digestate.

3. How it works up close
Continued

FIGURE 15
Building blocks of a circular economy—what's needed to win

EXAMPLES



A
Skills in circular product design and production

- Material choice optimised for circular setup
- Design to last
- More modularisation/ standardisation
- Easier disassembly
- Production process efficiency

B
New business models

- 'Consumer as user'
- Performance contracts
- Products become services

C
Skills in building cascades/ reverse cycle

- Collection systems: User-friendly, cost-effective, quality-preserving
- Treatment/extraction technology: optimising volume and quality

D
Enablers to improve cross-cycle and cross-sector performance

1. Cross-cycle and cross-sector collaboration facilitating factors
e.g., joint product development and infrastructure management through

- IT-enabled transparency and information sharing
- Joint collection systems
- Industry standards
- Aligned incentives
- Match-maker mechanisms

2. Favourable investment climate
Availability of financing and risk management tools

3. Rules of the game to quickly reach scale
Regulation in the areas of accounting, taxation, customs tariffs, customer and corporate responsibility, certification, standardisation

4. Education
- Awareness raising in general public and business community
- Integration of circular concepts in university curricula

Source: Ellen MacArthur Foundation circular economy team

Putting it all together—Building blocks of a circular economy

Despite their differences, the examples discussed—from fashionable mobile phones and long-lasting washing machines to textiles that cascade through multiple usage periods—all draw on the same essential building blocks of a circular economy (Figure 15).

Skills in circular product design and production. In nearly all of the examples, improvements in product design and material selection have reduced the cost of moving products into ever-tighter reverse circles, without compromising structural integrity or function. Besides material selection, which clearly plays a critical role in enabling circularity, other areas important for economically successful circular design are modular and standardised components, design for disassembly, design to last, and production process efficiencies that minimise waste. To optimise designs and materials for production and repeated use in closed loops, the core competency is thinking in terms of systems and being able to see 'the wood and the trees'. A clear view on the product, its nutrients (and suppliers), multiple customers, and the reverse process, explicitly supplemented by the circular economy principles outlined in Chapter 2, are a necessary aspect of optimisation. At present, the principles of segregating biological from technical nutrients and phasing out toxic materials are under-used and are therefore a priority. A few design changes can help achieve this segmentation. First, products can be modularised so problem elements can easily be isolated and replaced. As part of the same process, manufacturers can determine what long-lived materials should be used to form the core of a modularised product—i.e., the skeleton that lives on while modules and customisable add-ons are replaced. Design methods, also virtual ones, for modularising and standardising components, as well as flexible mounting techniques (e.g., snap fasteners instead of adhesives) are well known and can be used to make products easier to disassemble in preparation for their next round trip.

New business models. The ability to translate better designs with longer-lasting (component) usage into attractive value propositions is essential for more circular products to compete successfully against highly efficient, low-cost, linearly produced products. Changing from ownership to usage- and performance-based payment models (e.g., leasing, hiring—as in the washing machine example) and expanding the product definition to embed it in related services (e.g., power tools combined with building kits and training) are elements of such business models. Here, too, we expect an accelerating uptake over time as manufacturers—and their customers—become more familiar with such alternative models. Thomas Rau at Turntoo notes: 'The benefits of performance-based usage contracts are just now being fully understood and adopted by our corporate partners and customers.' This is not a one-size-fits-all solution—good knowledge of value chain participants' needs and ongoing innovation are required to find a fitting model. 'So far, we have not found a product for which our model does not work; and we have already looked at many different types', adds Rau. Renault points out that leasing models also allow full traceability of batteries and therefore guarantee them a high collection rate for closed-loop re-engineering or recycling.

Skills in building reverse cycles and cascades. Without cost-efficient, better quality collection and treatment systems with effective segmentation of end-of-life products, the leakage of components and materials out of the system will continue, undermining the economics of circular design. Building up the capabilities and infrastructure to close these loops is therefore critical. Collection systems must be user-friendly (addressing users' key reasons for making or not making returns, such as guaranteeing complete deletion of a user's phone data to allay privacy concerns), they must be located in areas accessible to customers *and* end-of-life specialists, and they must be capable of maintaining the quality of the materials reclaimed. Treatment and extraction technology is unevenly developed and must be increased in terms of volumes handled and the quality of the treatment. Whilst the challenges of raising

3. How it works up close
Continued

collection rates must not be underestimated (see the significant efforts of Europe's consumer electronics industry), initial steps can easily be taken already in today's environment (e.g., centralising refurbishment of light commercial vans to support it with the use of professional tools).

Enabling factors to improve cross-cycle and cross-sector performance. For the widespread reuse of materials and higher resource productivity to become as common and unremarkable as litter and landfills are today, market mechanisms will have to play a dominant role, but they will benefit from support by policy makers, educational institutions, and popular opinion leaders.

• Effective cross-chain and cross-sector collaboration are imperative for the large-scale establishment of a circular system. As an example, joint product development and infrastructure management (with, amongst other goals, that of driving down collection and manufacturing costs) can be facilitated by transparency along the value chain, available 'match-maker' mechanisms, establishment of industry standards (e.g., product labelling), and the alignment of incentives among business partners. Maintaining visibility along the value cycles on the whereabouts and the conditions of components across different stakeholders is essential for most circular business models to operate efficiently. B&Q points out, 'As a trading company, whilst we adhere to all health and safety legislation and proactively work to exclude/reduce problematic chemicals from our products—as we did when we led the way by significantly reducing the harmful chemicals in paint (now industry standard)—at this time we don't currently know every material contained in every product we sell. Understanding all the materials and components with every product and better labelling of these will be will be crucial for our success in the Circular Economy game'. This information needs to feed into well-developed company-internal databases and tracking systems, so that one can easily look up the origin, age, and range of potential applications—'a critical requirement for a high-performance remanufacturing system', says Jean-Philippe Hermine, CEO of Renault Environnement.

• 'Rules of the game' in the form of better aligned economic incentives from tax authorities and regulators on issues such as cost of landfill and labour costs could potentially speed up adoption of more circular business models. Professor Roland Clift notes on this topic: 'Some of the current incentives at systems levels are just perverse—for example, taxing labour instead of material. The one resource is non-renewable and in short supply yet free of taxes and the other is renewable but taxed'. Furthermore, regulation in the areas of customer and corporate responsibility, accounting, certification, and standardisation can help to quickly reach scale.

• All parties need access to financing and risk management tools to support capital investment and R&D. These points are closely linked to the above-mentioned 'rules of the game': a stable regulatory environment is a focal point for investors. As Andrew Page, a partner at Foresight Group, the asset management group pioneering environmental infrastructure investing in the U.K., puts it: 'A firm legislative and economic framework is the number one success factor for the transition towards a circular economy'. Cyberpac, a specialty packaging company, explains: 'The uncertain investment environment currently restrains large retailers from investing in new technologies'. Governments can create further funding stimuli by underwriting some of the risks associated with innovative, 'green' businesses. For instance, the newly established Green Investment Bank, an initiative launched by the U.K. Department for Business, Innovation and Skills, aims to 'accelerate private sector investments in the U.K.'s transition to a green economy' (including the waste sector), offering targeted financial interventions to overcome market failures such as risk aversion due to informational asymmetries and high transaction costs

• The shift to the circular economy must also be supported by the education system with integration into university curricula and outreach programs to increase awareness in the general public and business, science, and engineering communities—see also the sidebar on education and skills.

FIGURE 16 **Transition to a circular economy: Examples of circular business model adoption**

ILLUSTRATIVE

Building blocks of a circular economy	Examples: Mobile phone – From…	Mobile phone – To…	Light commercial vehicle (LCV) – From…	Light commercial vehicle (LCV) – To…	Washing machine – From…	Washing machine – To…
A Product design	Highly integrated product designs and low degree of component standardisation	Component standardisation (e.g., displays) and design for disassembly (e.g., clip-hold assembly)	Limited degree of modularisation (e.g., bolted connections in LCV engine bay)	Design for disassembly—wider design of engine bay and use of quick fasteners	Efficiency gains in energy and water consumption drive economic obsolescence and limit lifetimes	Regular software updates and upgrades of electronics and sensor systems post sale
B Business models	Low customer incentives to return devices after usage	Deposit payment or leasing models	Customer concerns about quality of refur-bished vehicles	Warranty offered on refurbished vehicles	Customer concerns about alternative business models	Creation of transparent, 'win-win' leasing contracts and effective marketing
C Reverse cycle skills	Limited development and choice of circular options	Automated disassembly and efficient tech-nologies (e.g., fault-tracking software)	Sub-scale refurbishing facilities	Centralised refurbishment plants with opti-mised workflows, allowing for eco-nomies of scale	Quality losses within inapprop-riate collection channels	Manufacturer-controlled collection, enabled by leasing models
D Cross-cycle and cross-sector coll-aboration	High damage/ loss rate along all reverse value chain steps	Industry-wide efforts to establish comprehensive collection and treatment system	University curricula for engineers still focused on linear system	OEM/sector initiatives to foster R&D of circular production methods	Diverging incentives of customers and producers in context of new ownership models	Specialised intermediaries enable alternative ownership models on larger scale

Source: Ellen MacArthur Foundation circular economy team

Systematically looking at these building blocks can yield specific ideas on how to move business practices forward from the current state. Figure 16 summarises what the concerted adoption of these levers could look like for some of our sample products. Whilst the list of enablers is long, the trends supporting a large-scale shift bode well for concerted action. Both resource prices and disposal costs are rising, increasing motivation to find new solutions. Progress in technological and material development supports longer-lasting and more reusable designs, increased visibility along the value chain enables all participants to better track products and materials, and consumer and corporations have grown more accustomed to contracts and usage practices based on performance instead of ownership.

The in-depth analysis of the different products selected for in-depth study suggest, which is summarised in the appendix, that a circular economy would shift the economic balance in three foreseeable ways. The shares of factor inputs will change: products will be made and distributed with less material but in some cases with more labour. Along the value chain, the relative importance of primary extraction and production operations will decrease, while new activities grow up around repeated use of products, components, and materials—a 're-sector' will emerge for reuse, refurbishing, remanufacturing, and recycling offering new opportunities for business building. The inherent economics of going circular seem to be applicable across a diverse set of products. In the following section we will look at how these findings would translate to opportunities at economy, company and user level.

3. How it works up close
Continued

Education and skills in the circular economy

The root of our existing educational system mirrors that of our economic system. Both emerged from the traditions and the world view that originated in the Enlightenment: the world is 'machine-like'. Science now reveals that the world is not especially 'machine-like'—it is more connected, feedback-driven, and reliant upon non-linear systems. As a result, with 'systems thinking' at its heart, a new scientifically based world-view is taking hold: that of the 21st century Enlightenment.

This shift is consonant with the ideas underlying the report—reinventing progress to reflect new insights into living systems. This scientific world-view recognises the importance of connection and flow, where feedback drives change, and where the old one-way idea of a 'cradle to grave' production system is replaced by 'cradle to cradle' just as the relationship of the part to the whole has reversed in emphasis. Our new concern with the state of the whole in relation to the part replaces a focus on the part in isolation.

The education system, if it remains true to its emphasis on mirroring the scientific state of play, and the economic concerns of dominant nation states and leading institutions, will wish to evolve to enable learners to grasp 'whole systems' design. This spans products, technologies, and molecules, materials, and energy flows, and makes explicit those links between the subject specialties, which are chronically underplayed at the present time.

Whole systems design may look like a conventional skills agenda, but such a view would underestimate it. Skills, crucially, are developed within a context and this leads to the question of 'which skills?' and 'how do they relate?' The emphasis in learning is likely to increasingly change through rebalancing* and making sure the skills underlying systems design are as practised and emphasised as the more established subjects.

In summary, the Foundation delivers an education programme that advances the STEM agenda (science, technology, engineering, and maths) and also a broader one that parallels how we are now remaking the world. Our model is supportive and yet anticipatory—bridging the worlds of education and business in a unique way.

*Examples of rebalancing include these pairs: problem solving/appreciation and reframing; analysis/synthesis; reductionism/whole system emphasis; closed cause and effect/multiple influences through time and space.

4

An economic opportunity worth billions
Charting the new territory

Maps out what moving towards a circular economy could mean on a macroeconomic level and how circular business models could benefit different market participants.

4. An economic opportunity worth billions
Charting the new territory

Given that we are still at the beginning of a journey to circularity, and assuming that we can identify profitable new options to establish circular setups (e.g., by applying insights from the selected products we examined), we believe that a substantial scale-up from the current starting position is possible and in fact highly likely. Whilst full quantification of a likely end-game will require further work, the case for rapid value creation is quite strong, particularly if we assume circular business practices reach a tipping point and thereafter see more widespread acceptance. Eliminating waste from the industrial chain by 'closing the loop' promises production cost savings and less resource dependence. The benefits are not merely operational but also strategic; not merely for industry but also for users; and not merely a source of efficiency, but also a source of innovation and growth. The potential identified so far represents only a small fraction of what could be possible if circular business models were to be applied at scale.

In the following chapter we will therefore explore:

How economies will win from substantial net savings on material and energy costs, improved mitigation of volatility and supply risks, higher multipliers due to sectoral shifts and reduced externalities

How companies will win by creating new profit pools and competitive advantage, building resilience against some of today's most strategic challenges, and expanding from their respective starting situations

How consumers and users will win by gaining more choice, experiencing fewer hassles from premature obsolescence, and enjoying improved service quality and secondary benefits.

Examining the benefits EU-wide

Our case studies show the positive business impact of circular business models on a product level. In Chapter 3, we described how we scaled up from the level of an individual product to the entire market for that product ('The Circularity Calculator'). Next, to see what the order of magnitude of economic impact might be if more businesses were to adopt these methods, we ran a second scale-up model, applying results from our selected product analyses to the eight sectors we see as having particularly high potential for adopting circular technologies. These eight sectors contain products of medium complexity (i.e., circular design principles could be incorporated initially with minor changes to existing technologies and processes) and medium usage periods (i.e., products will go through a number of product cycles in the next 15 years).[99]
Together, these eight sectors represent a little under half of the contribution the EU manufacturing sector makes to overall EU GDP—so this would not represent a narrow or isolated movement.

To perform our scale-up, we compared the total absolute cost savings on materials and energy (net of the required materials and energy used in the respective reverse cycle) for our selected products with the total input costs for each respective product. We chose this ratio because it factors out value-add across different products and industries, which is highly variable and potentially a distorting factor in our analysis.[100] We then applied the range of percentage savings from our detailed analysis to the selected target sectors to see what kinds of net material cost savings might be expected were all producers to adopt similar circular setups. We focused on the net material and energy cost savings as the net economic benefit of shifts in associated labour costs, the redirection of investments, and the split of savings between users and providers or across players along the value chain would likely vary across sectors and regions and therefore defies exact prediction.

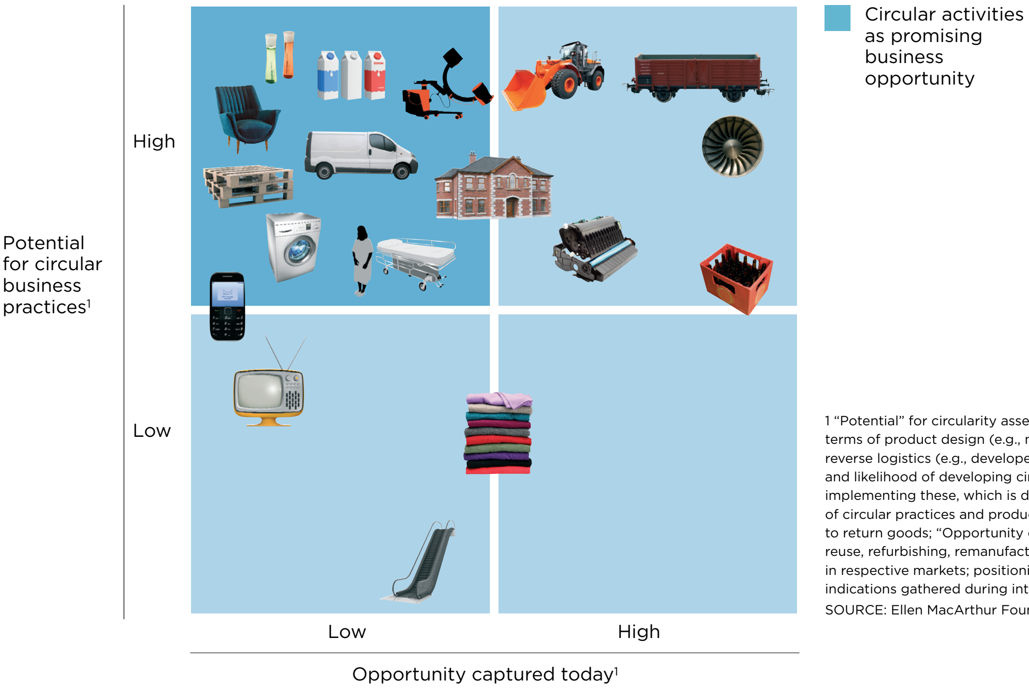
Of course, we do not expect all producers to instantly adopt circular business practices. Therefore, we established two

99 As discussed in chapter 3, the eight sectors, as categorised by Eurostat, are as follows: machinery and equipment; office machinery and computers; electrical machinery and apparatus; radio, television, and communication equipment and apparatus; medical, precision and optical instruments, watches and clocks; motor vehicles, trailers, and semi-trailers; other transport equipment; and furniture and other manufactured goods

100 For further details on the methodology discussed in this section, please see the appendix

FIGURE 17
Increasing circular activities is a promising business opportunity for a variety of products

ILLUSTRATIVE



1 "Potential" for circularity assessed by product's suitability in terms of product design (e.g., modularisation, non-toxicity), reverse logistics (e.g., developed remanufacturing activities) and likelihood of developing circular activities; and by ease of implementing these, which is driven by customer acceptance of circular practices and products, and convenience/incentive to return goods; "Opportunity captured today" is driven by reuse, refurbishing, remanufacturing and recycling activities in respective markets; positioning is validated by expert indications gathered during interviews.
SOURCE: Ellen MacArthur Foundation circular economy team

scenarios: in our 'transition scenario', we make assumptions mainly about changes in product designs—in line with current technologies and capabilities—and reverse-cycle skills. We typically assumed improvements in underlying collection rate increases of 20 to 30 percentage points, and roughly a 30 percentage point shift from recycling to refurbishing or remanufacturing activities. This is in line with interventions defined by some governments.

In our 'advanced scenario', we show the potential effect of a world that has undergone more radical change and has further developed reverse technologies and infrastructure and other enabling conditions such as customer acceptance, cross-chain and cross-sector collaboration, and legal frameworks. Our product analyses assumed further collection rate increases of 30 to 40 percentage points and an additional 5 to 10 percentage-point shift to refurbishing or remanufacturing (tighter loops that in general yield higher net material cost savings). Our intention was not to attempt to give an exact prediction of future economic composition, but to establish the order of magnitude and the nature of the lasting structural shift, whilst both grounding our analysis in current realities and showing the scope of potential medium-term impact towards 2025 were some of the current barriers to fade.

To further validate this approach of generalising the findings of our in-depth product analysis, we plotted several types of products on a matrix showing both their potential to adopt circular business models and capture value through these business models (Figure 17). This high-level analysis confirms that increasing circular activities would likely represent a promising business opportunity for a variety of other products—at least on the basis of sharing similar product characteristics. The two main components we examined are product suitability and ease of implementation. Within suitability, products with circular product-design characteristics (such as non-toxic materials, easy to disassemble, modularised), and those with developed reverse cycle processes (such as efficient collection, transportation, and treatment systems) stand the best chance at developing circular business models. On the implementation side, product categories in which circular business practices have already been successfully adopted, embraced by customers, and have established user-friendly collection systems represent a promising segment, as do those that are well suited for new usage (versus ownership) models (for instance, due to frequency of use/total cost of ownership). What does this mean in terms of specific products and business development? The products most suitable for circularity are those in the upper left-hand quadrant, from shampoos to hospital beds. Additional categories we see as potentially promising include some business lines that are already quite advanced, including construction equipment, heavy machinery, and aeronautics.

4. An economic opportunity worth billions
Continued

How economies win—Unlocking a multi-billion USD opportunity, fast and lastingly

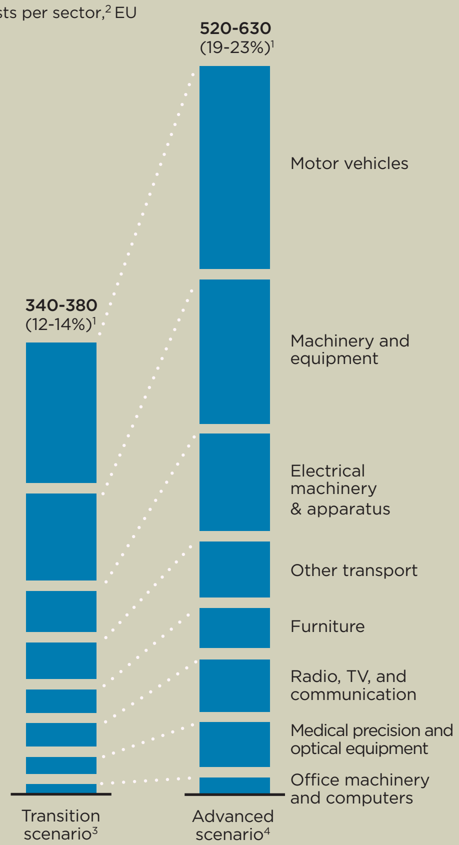
It is evident that reuse and better design in a circular economy can significantly reduce the material bill and the expense of disposal. But, from an economic perspective, can those savings produce a significant effect economy wide?

Substantial net material cost savings. Based on detailed product level modelling, the report estimates that the circular economy represents an annual material cost saving opportunity of USD 340 to 380 billion p.a. at EU level for a 'transition scenario' and USD 520 to 630 billion p.a., or a recurring 3 to 3.9% of 2010 EU GDP, for an 'advanced scenario', all net of the materials used in the reverse-cycle processes. (Figure 18). These figures are intended to demonstrate the order of magnitude of the savings that could be expected in a circular economy. Rather than trying to explicitly model the effect of circularity for the entire economy—which is highly dependent on many factors such as industry structure and conduct, elasticities, or the drive of companies to reap the circular potential—we decided to ground our estimate on the observed potential material savings for the products from our case studies. We limited the scale-up to those sectors that hold the most potential for mimicking the success of these products (i.e., products of medium complexity) and that contain products of medium-term usage periods (3 to 10 years), so that adoption of circular design and processes could actually affect the material balance over the next 15 years. These medium-lived products represent a little less than half of the contributions made by manufacturing to the EU's gross domestic product today—but clearly they do not represent an exhaustive list of all short-, medium-, and long-lived products that could be produced and delivered circularly. Similarly, our analysis only covers material and energy savings, as the net economic benefit of shifts in associated labour costs, redirection of investments, and the split of savings between users and providers or across players along the value chain would likely vary across sectors and regions and therefore defies exact prediction. We conclude, however, that the order of magnitude identified for Europe confirms that we are looking at a substantial opportunity at the economic level founded on a structural and lasting shift—a restorative circular economy. We would also expect significant economic potential for circular business models outside Europe. As a starting point, emerging market economies often are not as 'locked-in' to existing manufacturing models as advanced economies, and thus have the chance to leap-frog straight into circular set-ups when building their manufacturing sectors. Many emerging economies are also more material-intensive than advanced economies, and thus could expect even greater relative savings from circular business practices.[101]

ROUGH ESTIMATES

FIGURE 18
Adoption of circular setups in relevant manufacturing sectors could yield net material cost savings of USD 340 – 630 billion per year in EU alone

Net material cost savings[1] in complex durables with medium lifespans
USD billion per year, based on current total input costs per sector,[2] EU

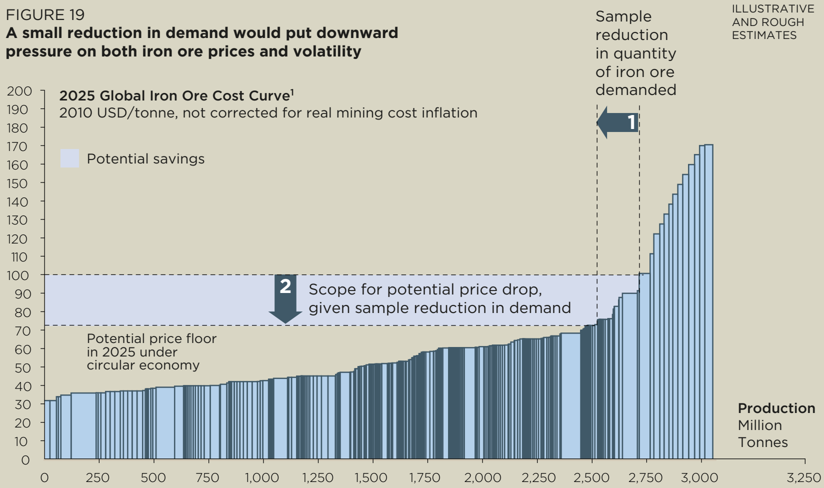


1 Material input cost savings net of material costs incurred for reverse cycle activities, percentages as share of total input costs in medium-lived complex product sectors
2 Most recent data for sector input costs on EU level come from Eurostat Input/Output tables 2007
3 Transition scenario: Conservative assumptions, focusing on changes in product designs, reverse cycle capabilities
4 Advanced scenario: Assuming more radical change especially in terms of further developed reverse-supply-chain competencies, and other enabling conditions like customer acceptance, cross-chain and cross-sector collaboration and legal frameworks

SOURCE: Eurostat Input/Output tables 2007 for EU-27 economies; Ellen MacArthur Foundation circular economy team

101 However, a projection on the size of the potential and adoption rate will require more in-depth analysis given the high variance in starting positions (e.g., collection rates in Europe tend to be higher than in other parts of the world) and different mix of economic activities

FIGURE 19
A small reduction in demand would put downward pressure on both iron ore prices and volatility



1 Note: this is not a projection of iron ore demand in 2025; rather it is an illustration of the impact of a demand reduction; see footnote 105 for more details.
SOURCE: McKinsey iron ore cost curve

Mitigation of price volatility and supply risks. Our product analysis shows the considerable effect that reducing downstream demand through circularity can have on upstream demand, especially by avoiding material loss due to inefficiencies along the linear value chain (reducing 1 tonne of final steel demand, for instance, saves over 1.3 tonnes of iron ore and over 5 tonnes of earth being moved). At present, the production of many raw materials falls at the far-right end of their respective cost curves, in some cases close to supply limits. The implication is frequent increases in pricing levels and volatility. Further acceleration of demand pressure is likely as three billion consumers are expected to enter the market until 2030. This means that any shift leftwards on the respective cost curves could have a calming impact on volatility. Other factors, such as speculative trading, however, could still lead to some volatility.

Steel is a good example. Looking at forecasted steel and iron ore demand over the next two decades, the incentives for reducing resource consumption become increasingly clear. By 2025, global steel demand is expected to rise to more than 2 billion tonnes per year, a 50% increase over current levels. Likewise, iron ore demand is forecasted to rise in parallel to around 2.7 billion tonnes.[102] From our case study analysis, circular business practices appear to be an effective way to limit the growth in iron ore extraction needs, which in turn are putting pressure on prices and volatility. Using data on steel savings gleaned from our analysis of refurbishing light-commercial vehicles (LCVs) and washing machines, we assessed the potential for reducing global iron ore demand across several sectors that we see as particularly ripe for savings. We focused our analysis on three steel-intensive sectors—the automotive, railway, and machinery sectors—which together represent around 45% of global steel demand.[103] We assumed conservatively that recycling rates remain constant and that only 25% of non-recycled products are refurbished in 2025—and then extrapolated what savings would be possible if the material savings from our LCV and washing machine refurbishment cases were scaled globally.[104] Our analysis shows that savings from global iron ore demand reductions, even under our conservative refurbishing rate, could well add up to 110 to 170 million tonnes per year (or 4 to 6% of expected 2025 demand). Whilst this may seem small, such volume changes would likely have a calming effect on pricing levels and volatility, as can be seen in our illustrative cost curve figure (Figure 19),[105 106] —though the exact savings in dollar terms would depend heavily on a variety of factors, including the volume and types of supply coming on line between now and then, and thus exact effects on steel or iron ore prices are quite difficult to forecast with any reasonable degree of confidence.

Growth multiplier due to sectoral shift and possible employment benefits. The three main macroeconomic sectors—the primary sector (extraction), the secondary sector (manufacturing), and the tertiary sector

102 Source: McKinsey Global steel and iron ore models; WSA

103 McKinsey Flat Steel Demand Model

104 Refurbishment requires 75 to 95% less steel than manufacturing a new product

105 This iron ore cost curve is illustrative. Cost is for standardised sinter fines, at the CIF price (cost, insurance, freight) for delivery at the Chinese border. Operational costs of individual mines are adjusted to a standardised 62% sinter fines product using value-in-use corrections and Fe dilution effects. No real cost inflation is applied to the cost curve between 2011 and 2025 for the purpose of the specific illustration of this exhibit. This cost curve also does not take into account the effect of real mining cost inflation. Example demand reduction in the exhibit is based on material savings of steel observed in product case studies and extrapolated to steel-intensive sectors deemed to have high potential for circularity—i.e., the automotive, railway, and machinery sectors.

Note:McKinsey's iron ore projections expect an increase in supply in the second and third quartiles of the cost curve—this increase will likely also put downward pressure on prices and volatility

106 It is worth noting that McKinsey's iron ore cost curve anticipates that new supply will also be added at lower price points, which would place additional downward pressure on both prices and volatility

4. An economic opportunity worth billions
Continued

(services)—would each have opportunities under a circular model, though we anticipate that the service sector would feel the biggest impact. The increased need for financing and leasing arrangements for a wide swath of products and reverse cycle services, as well as the need to expand services along the reverse cycles, would likely bring significant job growth in services (Figure 20). This shift could be particularly dramatic in developing economies, which at present are much more reliant on primary industries. Net employment effects will likely vary across sectors. The extraction sector—though it may face pressures on the virgin extraction side of its business—would also have opportunities to benefit from circularity. Smelters, for example, would almost certainly see expansion and new job opportunities in secondary extraction. The manufacturing sector is likely to undergo significant changes, given the removal of material bottlenecks and the need to adjust operations. Whether the newly generated remanufacturing volume will more than compensate for the pressure put on conventional 'linear' manufacturing depends in large part on the specific circumstances of different manufacturing industries. Given the strong fundamentals of the underlying business case (assuming comprehensive design changes to products, service delivery processes, etc.), adopting more circular business models would bring significant benefits, including improved innovation across the economy (Figure 21). While the exact GDP implications of more innovation across an economy are difficult to quantify, the benefits of a more innovative economy include higher rates of technological development, improved material, labour, and energy efficiency, and more profit opportunities for companies.

Finally, other sources report that a move toward a circular economy could potentially create moderate benefits, either in terms of job growth or employment market resilience. Sita Group, the waste management arm of Suez Environment, estimates that some 500,000 jobs are created by the recycling industry in the EU, and this number could well rise in a circular economy.[107] A recent report from the Centre for Manufacturing and Reuse argued that workers in the U.K. remanufacturing industry were less affected by the recession in the late 2000s than were workers in other sectors.[108]

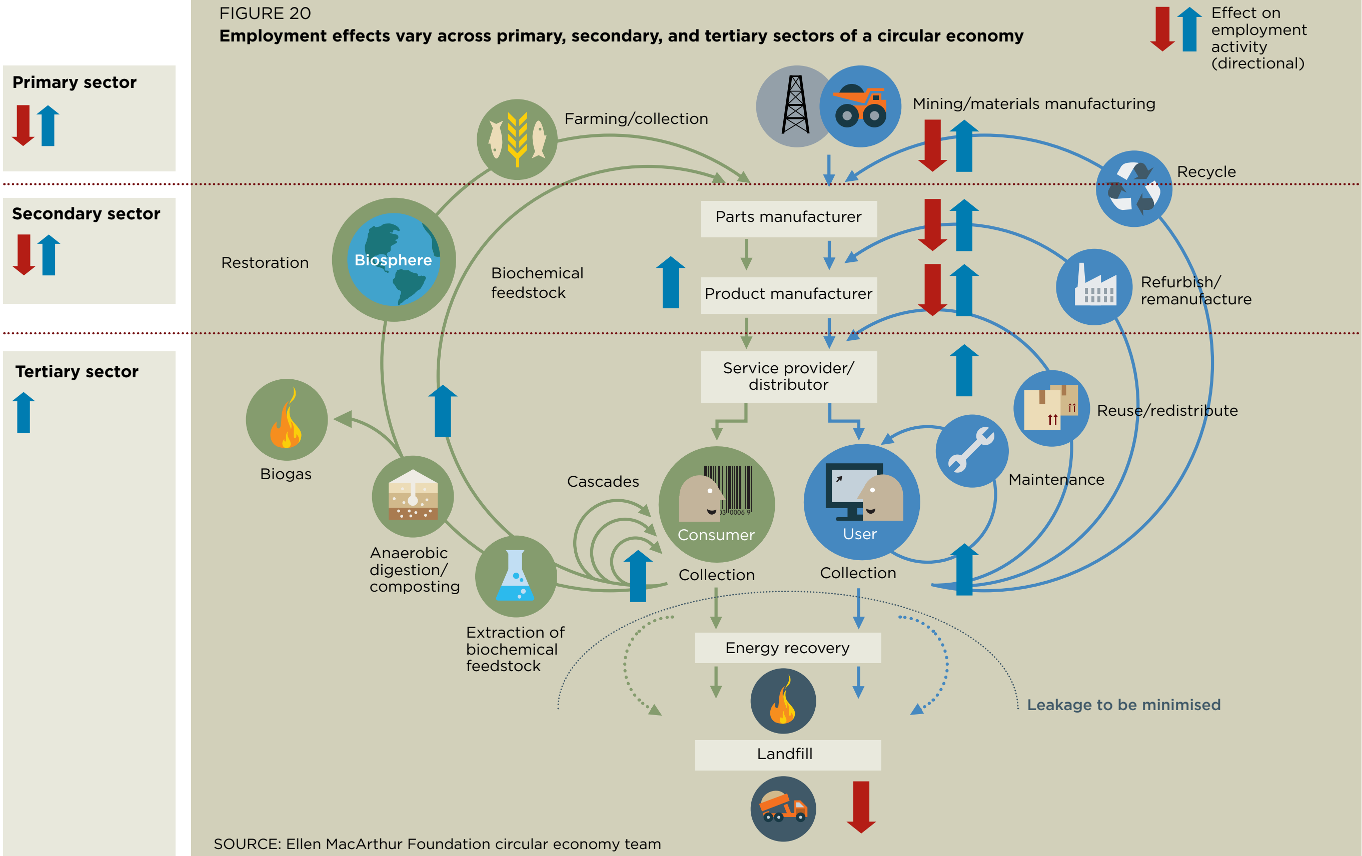
Reduced externalities. The circular approach offers developed economies an avenue to resilient growth, a systemic answer to reducing dependency on resource markets. It also provides a means to reduce exposure to resource price shocks and mitigates the need to absorb disposal costs—which consist of the loss of environmental quality and the public costs for treatment that is not paid for by individual companies. Higher reuse and remanufacturing rates for mobile phones in the EU, for example, could eradicate at least 1.3 million tonnes of CO_2e annually at 2010 production levels in our transition scenario, net of the emissions produced during reverse-cycle processes. In addition to the economic benefits, the exclusion of energy- or water-intensive production steps (like aluminium smelting) as well as a move towards less toxic materials (such as using more biological nutrients for consumables such as food packaging) could contribute to reducing pressure on GHG emissions, water usage, and biodiversity.

Lasting benefits for a more resilient economy. Beyond its fundamental value creation potential over the next 10 to 15 years, a large-scale transition to a circular economy promises to address fundamentally some of the economy's long-term challenges. Improved material productivity, enhanced innovation capabilities, and a further shift from mass production employment to skilled labour, are all potential gains that will significantly increase the resilience of economies. They will also provide fundamental changes that would make it harder to revert back to the troubles of a linear 'take-make-dispose'-based economy. Importantly, with its greatly reduced material intensity and a production base that is largely running on renewable sources of energy, the circular economy offers a viable contribution to climate change mitigation and fossil fuel independence. Moreover, the demonstrable decoupling of growth and resource demand will also slow the current rates of resource depletion.

107 French National Assembly, Rapport D'information No. 3880, October 26, 2011, p. 75

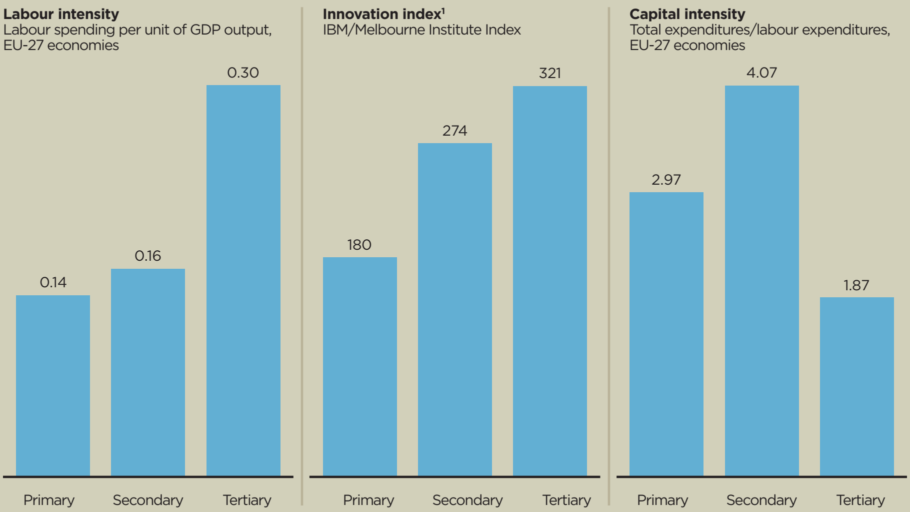
108 Remanufacturing in the U.K.: A snapshot of the U.K. remanufacturing industry, Centre for Remanufacturing and Reuse, August 2010

FIGURE 20
Employment effects vary across primary, secondary, and tertiary sectors of a circular economy



SOURCE: Ellen MacArthur Foundation circular economy team

FIGURE 21
Revamping industry, reducing material bottlenecks, and creating tertiary sector opportunities would benefit labour, capital, and innovation



1 Components of index include: R&D intensity; patent, trademark & design intensity; organization/Managerial innovation; and productivity

SOURCE: Labour intensity calculated using data taken from Eurostat Input-Output tables for EU-27; Innovation data from IBM/Melbourne Institute Innovation Index (covering Australian Industry), 2010

4. An economic opportunity worth billions
Continued

Factors driving premature obsolescence

What about the real (physical) limits to keeping products, components, and materials in the loop 'forever'? Products do eventually reach a physical limit, given the second law of thermodynamics.[109] Today, however, reaching these physical limits is more the exception than the rule. Other factors typically determine when a product is discarded—sometimes at a point when only a small fraction of the potential usage periods of its various components have elapsed. Unlocking the value of circularity will thus require tackling various forms of premature obsolescence, be they technical, fashion-related, economic, or regulatory in nature.

The 'weakest link' component. When one component breaks, the entire product with all its residual value is usually discarded before the end of its natural lifetime. The related term, 'planned obsolescence', assumes that designers and manufacturers deliberately do not address technical weak links in order to boost new product sales.

How to mitigate. Design products that wear out evenly—as Patagonia commits to doing for its apparel—or, if more appropriate, in a way that individual components can be replaced (Patagonia designs its garments so that they do not need to be taken apart completely if, for example, a zipper were to fail); encourage the manufacture and sale of individual components; rethink business models to make planned obsolescence less relevant (in systems where a "seller" retains ownership there is less incentive for obsolescence) (Figure 22).

Fashion obsolescence. Consumer products are commonly retired before the end of their useful lives due to fashion trends that encourage consumers to 'upgrade' to a new product for style reasons. For example, more than 130 million working but 'retired' mobile phones sit unused in the United States because their owners have purchased a replacement phone.[110]

How to mitigate. Consider ways to 'refresh' products—through cosmetic redesign—to provide consumers with a product that feels new and offers new value (software, casing, critical new components) but does not require new material input.

Economic obsolescence. When the cost of ownership outweighs the cost of buying and owning a new item it becomes economically obsolete. Automobiles, for instance, are sent to junkyards because of high maintenance costs, products are thrown away when their owners move and it costs more to transport the item than buy a new one, and old appliances that consume more energy are commonly discarded in favour of new, more efficient models. Finally, some products are discarded in response to government incentives such as those offered in the recent 'cash for clunkers' programmes.

How to mitigate. Design products to better allow for disassembly and strategic replacement of parts that the parts that are most reusable can easily be separated and reused and those most subject to technological progress and efficiency gains driving total cost of usage can be exchanged/upgraded more easily; create infrastructure facilitating return of products to manufacturers.

Financial/legal obsolescence. When the owner of a product is a corporation, products may be retired for accounting or legal liability reasons. Firms typically retire computers, for example, when the warranty expires.

How to mitigate. Rethink legal and accounting frameworks that compel firms to retire products before the end of their useful lives; establish infrastructure for ensuring that products that are retired when still usable are then refurbished or resold, rather than simply being discarded.

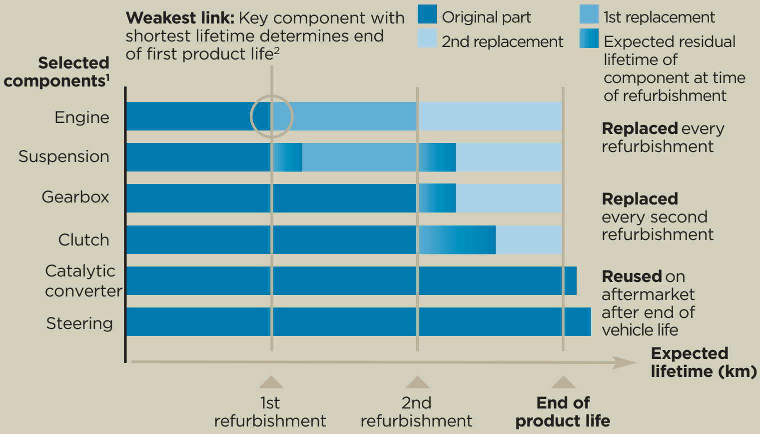
109 Tim Jackson, Material Concerns: Pollution, Profit and Quality of Life, London: Routledge Chapman & Hall, 1996

110 Slade, Giles, Made to Break: Technology and Obsolescence in America; Harvard University Press; 2006

ILLUSTRATIVE

FIGURE 22
Refurbishment helps to overcome a dynamic where 'weakest-link' components define a product's life — example light commercial vehicle

Proposal for improved state



1 Regular maintenance for easily replaceable parts (e.g., oil or tires)
2 Either by actual key component failure or pre-emptive reverse treatment (e.g., refurbishment)

SOURCE: Ellen MacArthur Foundation circular economy team

How companies win—Tapping into the profit pool opportunities of a circular economy

Companies are set to win in two ways. On the one hand, the circular economy will offer new profit pools in building up circular activities. On the other, the benefits of the circular economy will address a number of the pressing strategic challenges of today's businesses.

New profit pool potential along the reverse value cycles. Businesses that provide solutions and services along the reverse cycle are bound to reap attractive growth opportunities. Winners are already emerging today along the reverse cycle where they are supporting the ongoing migration towards a more circular economy (Figure 23).

Collection and reverse logistics, as seen in our case examples, are an important part of any system aiming to increase material productivity by ensuring that end of life products can be reintroduced into the business system. Classical waste management operators such as Veolia and Remondis are increasingly diversifying the fractions they can handle and divert from landfilling towards more recycling and even refurbishment operations. Logistics service providers are increasingly looking at reverse logistics not only as an opportunity to fill backhaul loads but as an attractive stand-alone business. DHL, for instance, established beverage distribution platforms in the U.K. that include the distribution, refilling, repair and collection of vending machines. OEMs like Caterpillar use their vendor and distribution system as a collection network for used engine cores, linking the cores to a deposit and a discount system to maximise the re-entry of used components into their rapidly growing remanufacturing operations.[111] Any reverse logistics system relies on its scale. 'Scale really matters in the reverse loop, improving the marginal cost position for collection and remanufacturing operations and fetching better prices for sales of larger quantities', explains Craig Dikeman at National Grid.

Product remarketers and sales platforms are rapidly expanding and growing into substantial enterprises, facilitating longer lives or higher utilisation and hence utility levels for mass-produced goods. The term 'collaborative consumption', coined by Ray Algar, a U.K.-based management consultant, and popularised by Rachel Botsman and Roo Rogers, gives a name and is injecting fashionability into time-honoured activities such as sharing, bartering, lending, trading, renting, (re-)gifting, and swapping. In a sense the term is a misnomer, in that it refers to 'usage' contracts rather than 'consumption'—but, in any case, the model has proven wildly popular. The formats it entails build on patterns familiar from church bazaars, 'rent-a-tuxedo', and 'party-plan' sales formats and, if well designed, do not require consumers to shift their behaviour outside of their comfort zones. The omnipresence of network technologies and social media is dramatically increasing reach and reducing distribution cost for providers of sales and remarketing services. In the consumer-to-consumer environment, market players like eBay and Craigslist led the way to increasing the amount of second-hand goods traded online. Amazon too has created a successful open platform for selling used products—giving suppliers access to almost 150 million customers worldwide and applying a very granular understanding of customers' individual needs and interests. In the business-to-business environment as well, typically more specialised companies

111 Corporate annual reports 2005 to 2010; Product-Life Institute website (http://www.productlife.org/en/archive/case-studies/caterpillar-remanufactured-products-group)

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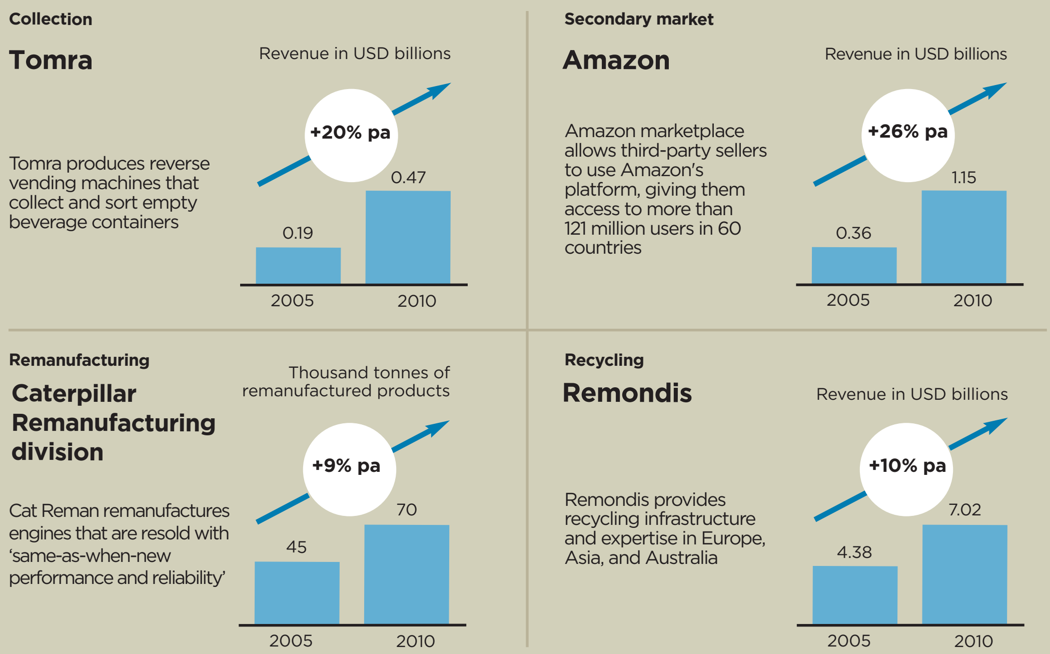
are offering a sales platform for used and refurbished products. In the European remanufactured medical devices sector, literally dozens of providers such as Pharma Machines offer these services with dedicated sales platforms.

Parts and component remanufacturing and product refurbishment can be considered the hardest loop to close on the path to a more circular economy because of the specialised knowledge required. Collection, disassembly, refurbishment of products, integration into the remanufacturing process, and getting products out to users all require specialised skills and process know-how. Consequently, most of the case examples at scale are subsidiaries of existing manufacturers, although large-scale independent operations exist, Cardone Industries, for example, has been supplying the U.S. automotive aftermarket with remanufactured cores for over 40 years. Original equipment manufacturers do have a number of advantages. For instance, Caterpillar applies product and process know-how from their new-equipment business to their diesel engine remanufacturing operation; they also use their existing dealer network and aftermarket service clout to ensure that components find their way back from the customer to their remanufacturing facilities. Caterpillar engineers study returned components and continually improve the company's ability to remanufacture them at lower cost and higher quality.[112] This allows Caterpillar to provide the same warranty for 'reman' engines as for new products. Product insights passed on from the remanufacturing/refurbishment plant to an OEM's designers and engineers not only add to future remanufacturing margins but can also help to improve the performance of the original cores. Renault, another example, already has a process in place to make sure that its new remanufacturing workshop for electric vehicle batteries feeds engineers' insights into failure modes back into the new product development process. Critically, many OEMs also see it as a strategic priority to serve in their aftersales markets—for brand protection, customer retention, or volume reasons—and remanufacturing offers them a way to do this with attractive margins. Cisco confirms, 'Refurbishing various kinds of end-of-life products is not only an economically viable business opportunity, it also provides an excellent means of building relationships with new customer segments'.

Material recycling systems systems are well established. They typically take the form of regionally structured multi-user organisations (such as the many product-category-specific systems in Europe, from batteries to packaging) or are company specific (reintroducing production waste from car manufacturing into the material flows, or Nespresso's collection and recycling of spent capsules). Both group and single-company solutions require a standard purity level suitable for high-quality recycling processes. Consequently, the market has generally developed into regionalised, specialised players with natural barriers to growth beyond their starting footprint. A number of companies have nevertheless started to enlarge the scale and scope of their operations by adding new geographic regions and further material fractions to their portfolio. Tomra has used its technological capabilities to provide the technology for large-scale, nation-wide collection schemes (e.g., PET bottles). The company has grown at close to 20% per annum. Looking ahead, it plans further improvements in technology to reduce the burden of costly separation and pre-sorting schemes and therefore aims to achieve higher recycling yields at lower cost, resulting in rapid and profitable growth for recyclers. Similar technology could be applied to the process of taking back products for remanufacturing and refurbishing. Another company that is optimising recycling systems is Renault, which has long worked on augmenting the recycled content of its vehicles. 'While 85% of the weight of a car is typically recycled, only 25% of the material input for new cars consists of recycled material', says Jean-Philippe Hermine at Renault Environnement. Because this disconnect is mainly due to concerns about the quality of recycled materials—in particular plastics—Renault is now developing ways to better retain the technical and economic value of materials all along the car's life cycle. It is not only actively managing a flow of quality material dismantled from end-of-life vehicles and enhancing the actual recycling processes, but is also adjusting the design specifications of certain parts to allow for closed-loop, or

112 Corporate annual reports 2005 to 2010; Product-Life Institute website (http://www.productlife.org/en/archive/case-studies/caterpillar-remanufactured-products-group)

FIGURE 23
The circular economy is creating a new 'reverse' sector



SOURCE: Tomra annual reports (2005, 2010); Ixtens research (based on Amazon SEC filings, Forrester analysis); Caterpillar annual reports (2005, 2010); Remondis annual reports (2005, 2010)

'functional' recycling. This way, end-of-life vehicles are turned into high-grade materials appropriate for new cars, and downcycling is avoided.

Enabling business models that close reverse cycles. Closing the reverse cycle may well require yet more new businesses to emerge. For instance, providing users and suppliers with sufficient incentives may be difficult due to higher transaction costs and inability to agree on specific rates. Turntoo, a company with a vision of moving towards product use based on performance contracts rather than on ownership, fills the void by operating and financing schemes that are based on offering products such as office interiors (e.g., lighting) net of their material value. Such schemes provide advantages for all participants: customers do not need to part with cash for the material portion of the products they are using; Turntoo generates a revenue stream through its services as an intermediary; and participating manufacturers regain their materials at a guaranteed price—which is especially attractive at times when commodity prices are on the rise. In one version of this win-win scheme, Turntoo has adapted the conventional leasing model to accommodate the exclusion of material value from the price. In another, the company—working like a broker—provides the product to the user for a certain number of years of usage. At the end of this phase, Turntoo buys the product back from the customer at the price of the embedded raw material at the time of original sale. At this stage, the manufacturer can decide to refurbish the product for reuse or extract the material from the product for sale. Turntoo believes this dynamic will align incentives and encourage manufacturers to design products for the longest life possible. The firm's CEO, Thomas Rau, explains: 'The different economic incentives of our model drastically transform the way that people look at product and process design along the value cycles, and companies are, for example, starting to remove the break points of current designs'.

4. An economic opportunity worth billions
Continued

Circularity and Finance

The spread and mainstream adoption of circular business models would have several implications for the financial services sector—and could lead to new opportunities for financial institutions.

New financing models. In the circular economy, new ownership models—in which customers no longer purchase as many goods directly, but rather use them for a fee and then return them—would demand new methods of financing or significant expansion and adaptation of existing methods. The leasing of goods in transactions in both the business-to-business (B2B) and the business-to-consumer (B2C) segment would likely become more common, requiring a commensurate uptick in services relating both to structuring and managing leasing arrangements.

Traditional financing demand. Increased demand for traditional financing might well present a parallel opportunity. We expect significant new demand from firms attempting to reconfigure production methods. In addition, the broadened 'reverse cycle' sector of firms needed to support circular business models—such as collection businesses, refurbishment operations, or remarketing specialists—would also require financing support. There remains, of course, the question of whether these capital expenditures would simply replace other R&D expenditures, but it seems highly probable that firms' transition efforts would generate some new business for the financial services sector.

Indirect effects. A shift in corporate business models could affect the financial services sector in various other ways. For instance, corporate lending might come to replace consumer financing of purchases—requiring more robust solutions for product guarantees and insurance coverage that could lead to opportunities for banks and other financial services providers. Separately, given the likelihood of reduced commodity price volatility under a circular model, the business of selling instruments that hedge against changes in commodity prices would likely recede in relative importance.

Economic effects. An overarching indirect impact on the financial services industry—and, indeed, on all other industries—would result from the increase in capital productivity we expect to result from a shift from the primary and secondary sectors to the tertiary sector under a circular economy (Figure 21). Given that capital productivity is a driver of long-term economic growth, such a shift could have profound economic implications.[113] Achieving a healthy transition would rely heavily on the financial services sector serving as a clearinghouse for capital—helping parts of the economy with capital surpluses invest this money more productively.

113 Such a shift would be particularly welcome given the 'equity gap' cited by the McKinsey Global Institute in a recent report, The Emerging Equity Gap. In the report, MGI forecasts a USD 12.3 trillion gap between the amount of equity capital that investors are willing to supply and the amount that companies need to fund growth in the next decade. Any mechanism, such as the circular economy, that would help stimulate capital productivity and free up investment dollars might therefore have a very significant effect on economic growth

Financing. Individual companies and groups of companies will need not only support with change-in-ownership models but also funding for R&D and new technologies. As in the linear economy, the financial sector has an important role to play in the circular economy, both in transition and steady state. Because of the numbers of cases banks handle, they are typically also far more experienced and therefore better at structuring long-term return models than corporations alone.

Mitigation of strategic challenges to build resilience and competitive advantage. Circular concepts could address challenges such as an intensified cost-price squeeze, shorter product life cycles, geographic and political supply risks, increased commoditisation of products, and decreased customer loyalty.

Reducing material bills and warranty risks. Through reselling and component recovery, a company can significantly reduce its material bill. In the case of mobile phones, remanufacturing can reduce material costs by up to 50%—even without the effects from yet-to-be-created circular materials and advanced reverse technology. In addition, 'building to last' can also reduce warranty costs. A utility provider able to reuse materials that are installed in fixed infrastructure (e.g., overland electric power lines) can reduce the utility's exposure to price hikes and supply risks.

Improved customer interaction and loyalty. 'Instead of one-time transactions, companies can develop life-time service relationships with their customers,' says Lauren Anderson, Innovation Director at Collaborative Consumption Labs. With 'consumers' of durable goods now becoming 'users', companies will have to evolve as well. New, long-term customer relationships will be vital to smooth the processes of providing maintenance, product upgrades, and other product-related services, and coaxing customers to return products at the end of each usage cycle. Moreover, with rental or leasing contracts in place, companies can gather more customer insights for improved personalisation, customisation, and retention. As Cisco puts it: 'We think that broadening our focus beyond pure-play manufacturing—to enhance our service offerings as well—will deepen our relationships with our customers and create more value for everyone involved'. Providing end-of-life treatment options and incentives to use them could increase the number of customer touchpoints and help build a technology pioneer's image.

Less product complexity and more manageable life cycles. Providing stable, sometimes reusable product kernels and treating other parts of the product as add-ons (such as software, casings, or covers) enables companies to master the challenge of ever-shorter product life cycles and to provide highly customised solutions whilst keeping product complexity low.

Innovation boost due to system redesign/rethinking. Any increase in material productivity is likely to have an important positive influence on economic development beyond the effects of circularity on specific sectors. Circularity as a 'rethinking device' has proved to be a powerful new frame, capable of sparking creative solutions and boosting innovation rates.

How consumers and users win—more choice at lower cost and higher convenience

The net benefits of a closer loop are likely to be shared between companies and customers. Marks & Spencer explains: 'Our first closed-loop project has demonstrated that it is attractive to consumers—for high-value materials like cashmere and wool the cost of goods for virgin material would be the double, so we would have to sell at a much higher price'. And yet the examples in this report indicate that the real customer benefits go beyond the immediate price effect. Michelin's pay-per-kilometre model means less upfront pay-out, less stock-keeping, and overall lower cost for fleet

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managers. Moreover, advantages extend to reduced costs of obsolescence, increased choice, and secondary benefits.

Reduced obsolescence with built-to-last or reusable products will improve budgets and quality of life. For the customer, overcoming premature obsolescence will significantly bring down total ownership costs and deliver higher convenience due to avoiding hassles associated with repairs and returns.

Choice is increased as producers can tailor duration, type of use, and product components to the specific customer—replacing today's standard purchase with a broader set of contractual options. 'Looking at the world from a circular design perspective will allow us to further segment our customer base to provide better service at more competitive cost,' says B&Q.

Secondary benefits accrue to the customer if carpets also act as air filters or packaging as fertiliser. Needless to say, customers will also benefit from the drastic reduction of environmental costs associated with circularity.

On a daily basis, consumers will experience this bundle of benefits in keeping with their individual preferences and circumstances. The repair-and-replacement chores currently caused by 'weakest link' elements will be reduced, decreasing expense and hassle, and expanded options for customised products for home and work will enable new forms of personal expression and problem-solving (customisation may be the new shopping). Furthermore, well-made goods and 'two-in-one' products with multiple functions might well bring both aesthetic and utilitarian benefits. Whilst the transition to a circular economy will bring dislocations, the more productive use of resources and materials should have a stabilising effect on the economy, giving the world some 'breathing room' as it deals with the strains of expanding and ageing societies.

5

The shift has begun
‘Mainstreaming’ the circular economy

Proposes winning strategies for businesses to bring the circular economy into the mainstream and a roadmap for an accelerated transition towards a circular economy.

5. The shift has begun

'Mainstreaming' the circular economy

Our economies remain strongly locked into a system where everything from production economics to contracts, and from regulation to mindsets, favours the linear model of production and consumption. In that linear world, reuse will indeed replace demand for a company's incremental sales and weaken revenue and profits.

This lock-in, however, is getting weaker in the wake of powerful disruptive trends that will shape the economy for years to come:

First, resource scarcity and tighter environmental standards are here to stay. This perception is increasingly accepted by the business sector. In a 2011 McKinsey Quarterly executive survey, the number of respondents who pursue sustainability initiatives to reduce costs or improve operating efficiency was up 70% over the previous year.[114] Along with a changing appreciation of the business rationale, investment in environment-related areas has increased dramatically. According to a joint report by the World Economic Forum and Bloomberg, global investment in green business initiatives in 2010 alone totalled USD 243 billion, a 30% increase over the prior year.[115] Given their superior resource performance, it seems likely that investments in circular businesses will be systematically rewarded over the 'take-make-dispose' ones.

Second, we now possess the information technology that will allow us to shift. We can trace material through the supply chain (e.g., using RFID), identify products and material fractions (using the breathtaking computing power of modern sorting technology), and track the product status and costs during its use period (as already practiced by some car manufacturers). Professor Clift points out that whilst the idea of a circular economy has been around for some time, further development and wider acceptance of end-to-end costing and better tracking of products, combined with more acceptance of re-engineering and development of the necessary capabilities, will ease widespread adoption. Most importantly, there are social networks now that can mobilise millions of users around a new idea instantaneously—from motivating consumer awareness to facilitating concrete action (e.g.,'Carrotmobs').

Third, and on a related note, we are witnessing a pervasive shift in consumer behaviour. Organised car sharing is growing at a rapid clip—from fewer than 50,000 members of car-sharing programs globally in the mid-1990s,[116] to around 500,000 in the late 2000s.[117] According to Frost & Sullivan, this number is likely to increase another 10-fold between 2009 and 2016, and the total number of cars in the car-sharing market is likely to grow about 30% per year during this period.[118] At this pace, by 2016 the car-sharing industry would replace the production of more than one million new vehicles. The list of 'shareware' extends beyond cars, however, and in some regions even includes articles of daily use, such as bicycles, toys, musical instruments, and power tools.[119] In Germany, for instance, 'swap in the city' garment exchanges have become popular and are magnets for urban consumers. Taken together, circular business design seems finally poised to move from the sidelines and into the mainstream. The mushrooming of new and more circular business propositions—from biodegradable packaging to utility computing and from non-toxic ink to sewage phosphate recovery—confirms that momentum is building.

And yet, to capture the prize of the circular economy some significant barriers must be overcome. What is needed for this revolution to take place?

The transition is likely to be a messy process that defies prediction, and both the journey and the destination will no doubt look and feel different from what we might imagine today. We expect this transition to be as non-linear as its inner workings, as a dynamic series of leaps at an accelerating pace. Why?

The Ellen MacArthur Foundation and its partners believe that an accelerating adoption may result, first, from today's fast proliferation of consumption patterns and, second, from the scale-invariance of many circular solutions: once a tracking system or a collection system is in place, additional volumes come at very low extra cost—the 'internet principle'. We also see a 'backlog' of existing technology, design, and contractual solutions that has existed for some time and that can now easily multiply as input-cost

114 'The business of sustainability: McKinsey Global Survey results', McKinsey Quarterly, October 2011. The percentage of respondents who pursue sustainability initiatives rose 14 percentage points, from 19 to 33% of all respondents

115 Green Investing 2011: Reducing the Cost of Financing, World Economic Forum and Bloomberg, April 2011, p. 6

116 Susan A. Shaheen and Adam P. Cohen, "Growth in Worldwide Carsharing: An International Comparison", Transportation Research Record: Journal of the Transportation Research Board, 2007, p. 84

117 Frost & Sullivan, "Sustainable and Innovative Personal Transport Solutions—Strategic Analysis of Car sharing Market in Europe", research report, January 2010

118 Frost & Sullivan, "Sustainable and Innovative Personal Transport Solutions—Strategic Analysis of Car sharing Market in Europe", research report, January 2010

119 http://www.zeit.de/2011/51/Meins-ist-Deins ratios and demand pass critical levels. The mining houses are demonstrating how new technologies and the need to address overall ore grade erosion can accelerate circular businesses: Anglo-American and others are now developing businesses based on processing materials previously considered mining wastes, such as tailings and fractions of the overburden. Some companies are taking this a step further by designing their production processes in a way that enables them to reap additional rewards from the products they produce when they return after their first usage period. Desso, the Dutch carpet manufacturer, offers carpets today that will be easier to regenerate and reuse more cost efficiently when they return in the years to come.

These factors will make it hard to predict with any certainty how quickly principles of the circular economy will become mainstream. Different times to impact will prevail: some products have long cycles, some do not. And some companies can start off circulating a stockpile of returned goods, end-of-life products, and process wastes; others need to recover these resource volumes first and wait for improved designs to unlock the full potential of 'going circular'. Still, we could imagine that circularity will take hold in two distinct phases.

During a pioneering phase over the next five years, we would expect entrepreneurial companies to scale up circular models from their piloting state, largely relying on the existing market environment (with today's input cost ratios, pioneer customers, and producer responsibility legislation) and their own capabilities, especially around making rapid changes to their end-of-life treatment, service model innovation, and product designs. During the mainstreaming phase thereafter, towards 2025, when we would expect the economy to have developed more cross-sector and cross-chain collaboration, built up a reverse infrastructure, and put in place favourable regulation, we will see a proliferation of offerings—possibly to the point that users have a true 'circular option' for all important product categories.

Roadmap towards 2025—Rapid pioneering and broad-based mainstreaming

The pioneering phase

Recent decades have served to confirm the technical viability of circularity for a large number of products and service models. The next five years will be the pioneering phase in which circularity's commercial viability must be proven more widely. Customers and producers could capture the savings opportunity of the 'transition scenario' if their conduct shifts sufficiently (across all three sectors), as outlined in previous chapters. For Europe alone, the material savings could well be in the order of magnitude associated with our transition scenario of 12 to 14%, worth USD 340 to 380 billion per annum[120] (net of material expenditures during the reverse-cycle process). As they capture these benefits, industry pioneers will build competitive advantage in a number of ways:

Companies will build core competencies in circular design. Circular product (and process) design requires advanced skills, information sets, and working methods that today are not readily available. Whilst much of the 'software' for the transition such as cradle to cradle and the performance economy has been on the drawing board and in development by thought leaders for some time, this knowledge must be brought into the production environment, debugged, refined, and rolled out into commercially viable solutions at scale. At the process level, the core of the process design challenge is likely to be the need to overcome internal incentive mismatches (such as those between organisational units measured on their success in driving new product sales and other units aiming to reduce material consumption through remanufacturing and remarketing of used products).

Companies will drive business model innovation, explore new service models, and challenge today's orthodoxies of ownership-driven consumption: 'Forget ownership, it is performance that counts'. Turntoo perceives ownership as a key element to achieve the preservation of resources. 'By shifting consumer perception from products to performance, manufacturers are challenged to approach their products as 'resource

120 See also 'Examining the benefits EU-wide' and Figure 18

5. The shift has begun
Continued

depots' and the raw materials will remain available for future generations'. Treating material usage as a service allows companies to benefit over time from improved material productivity and product longevity, which would not be rewarded in today's short-term price competition at the time of sale. Business model innovation will also include collaboration across value chains to establish materials standards and information flows that support circularity. We see a variety of steps companies are likely to take to help drive this innovation. First, companies with significant market share and capabilities along several vertical steps of the linear value chain could play a major role in driving circularity into the mainstream by leveraging their scale and vertical integration, much as any other business might. Whilst many new models, materials, and products will have to come from entrepreneurs, these brand and volume leaders can also play a critical role. Secondly, we envision 'missing link' roles where smaller firms will find market opportunities—for instance, Turntoo's 'market maker' role—facilitating new relationships between producers and consumers who are interested in pay-per-performance models.

Jointly, pioneering companies will create the capacities for the reverse cycle. Current infrastructure is not well equipped to fulfil the requirements of the circular economy. In addition, Europe would need to build up or strengthen current remanufacturing skills, 're-logistics' (return or reverse transport and handling), storage, and information transfer capacities to keep materials and components identifiable as they cycle through different uses and applications. Pursuing pioneering strategies focused on both sector-wide solutions (e.g., within advanced industries) and regional solutions (e.g., shared collection schemes within Europe, a single country, or even a large metropolitan area like London or Paris) is likely to yield the fastest proof of concept and highest return by exploiting economies of density and local scale.

Towards 2025: The mainstreaming phase

There is a chance for circularity to go mainstream and to capture (or exceed) the benefits of the 'advanced scenario' in the range of 19 to 23%, which is equal to about USD 520 to 630 billion p.a. in Europe[121] alone, net of the expenditures on material during the reverse-cycle process. To realise this potential, however, more transformational action is needed on the part of the corporate sector working jointly with government. Advancing the current taxation, regulatory, and business environment to support pervasive adoption of the circular economy will require joint effort to foster cross-chain collaboration, develop collection systems at scale, redirect marketing efforts, provide education, and involve service industries (such as the financial sector).

Although we see businesses themselves as the primary driver of a shift towards circularity, the public sector may also have a role to play. Specifically, governments can help stimulate fast-track adoption of circular business opportunities by adjusting the enablers to shift the rules of the game. 'The government/regulatory approach' typically can be further broken down into different plays:

Organising re-markets (and fighting leakage). Today, 'reverse cycles' are significantly impaired by the high cost (and low convenience) of collection, lack of aggregation facilities, and leakage from the system through subsidised incineration or undue exports to emerging economies where materials are often downcycled using low-cost labour, typically with high losses and under poor working conditions. Achieving scale in collection is critical and will benefit from appropriate landfill gate fees, minimum return or collection quotas, and efficient collection rules.

Rethinking incentives. Taxation today largely relies on labour income. Resource and labour market economists have long argued that labour as a 'renewable factor input' is currently penalised over material and non-renewable inputs in most developed economies. They promote a shift of the tax burden away from labour/income and towards non-renewable resources.

Igniting innovation and entrepreneurship, stepping up education. Circularity will come as a bottom-up revolution, a natural response/defence as the resource cost squeeze and volatility intensify. But such new products and businesses will take hold faster

121 See also 'Examining the benefits EU-wide' and Figure 18 if entrepreneurship and venture investment are welcomed and supported. Strengthening the education of future generations of entrepreneurs, designers, chemical and industrial engineers, of procurement officers, and product managers, will be critical to completely rethink and overturn today's linear world.

Providing a suitable international set of environmental rules. In the least intrusive way, government and public sector entities can help to foster cross-chain collaboration by establishing standards and guidelines. Product labelling is an important lever to ensure proper treatment in the reverse loops regarding non-toxicity, purity, or handling issues.[122] Another is to phase out (toxic) chemicals that—if blended into waste—significantly impair recycling or reuse of a much larger set of products and materials. Finally, governments should re-examine certification programs to enable new ways of confirming the viability or safety of circular products. As one example, no certification guideline currently exists for second-hand wind towers, so verification bureaus typically cannot certify them—a major barrier to growth in the secondary market, given the liabilities incumbent in operating an uncertified used wind tower.

Leading by example and driving scale up fast. There are also many opportunities for governments to use their own procurement and material handling to accelerate the spread of circular setups. In the U.S., the policy to move towards procurement of performance-based services (rather than products) has created a market of significant scale. In its convenor or 'matchmaking' role, a government can initiate concerted efforts among different companies in the value loops that are large enough to overcome diseconomies of scale. One example is in phosphorus markets, where a few governments have started actively trying to help businesses extract value from sewage sludge. In Germany, for instance, the Federal Environmental Office recently announced a goal of retrieving phosphorus from sewage, and Sweden set up an action plan in 2002 aimed at recycling 60% of phosphorus, mainly through making sewage available for reuse.[123] There may also be a role for intermediate, 'convener' institutions in some countries. In the U.K., for instance, an organisation called the Waste & Resources Action Programme, or WRAP, aims to bring community leaders and government leaders together to improve resource efficiency across the country.

How to get started? Five ideas on how pioneers could drive the circular economy to breakthrough

While the above suggestions focus on the broader transformation of the economy as a whole, we are putting forward five specific ideas worth pursuing as they are likely to drive benefits rapidly for the pioneers in the public and private sectors and might allow them to get a head start on building competitive advantage:

Tightening circles along your own supply chain. Firms with strong influence and control over their current supply chains (e.g., in automotive, consumer electronics, trading organisations and retailers) and those that exchange large volumes of products with a limited set of business partners (e.g., B2B interfaces in the machining, manufacturing or chemical sectors) could map out the leakage points of their current linear set-ups and apply their clout to move others in the chain towards tighter circular setups. Desso, for example, managed to convince suppliers to comply with its higher standards of non-toxicity and purity of materials, necessary to allow it to achieve higher recycling rates for its carpet tiles and to keep material in the technical nutrient loop longer. Renault, in another example, aims to strengthen its reverse supply chain by helping is vendors develop skills, redistributing margins along the chain, and hence rendering the business model more viable for all players, and providing a more reliable outlet for recovered materials and components. In Europe, potential capability gaps (in collection and sorting, for instance) can be overcome for many types of products by tapping into the reverse logistics and rapidly expanding the capability set of 'waste management' firms—making 'resource management' a more appropriate label for their activities. On this front, Renault has chosen to partner with Suez Environnement/Sita in order to provide access to a steady supply of components and materials.

122
Knowing what is included in a product is vital information to ensure proper treatment or even completely avoid complex separating procedures altogether, especially for plastics, which are extremely hard to distinguish without labelling due to similar product density and chemical and physical properties.

123
McKinsey research on sludge monetisation

5. The shift has begun
Continued

Looking for like-minded players in the sector could then easily allow for national industry consortia to emerge fast, as firms are facing similar pressures at parts of the value chain that do not necessarily lead to conflicts of interests or competitive gamesmanship (like forming national or regional consortia to deal with the ever-increasing volume of electronic waste). This concern is expressed in public opinion polls and consumer surveys, and is reflected in new interest in above-ground 'urban' mining for scarce and valuable materials and components.

Catch the wave at the start. We are at the beginning and will see the formation of a number of new industries and product categories that will transform the economy by themselves. Free of pre-defined structures, such as established design principles, processes, and disposal routes encrusted in brick and mortar or contract interfaces in silos, several entire industries (e.g., the solar panel industry) or emerging product platforms (such as those for electric or lightweight vehicles and car batteries) have a one-time opportunity to embed circular principles right from the design stage of the product, via material choices, through the establishment of service-based delivery models, right up to the optimised setups for circular reverse cycles.

Activate your (local) community. As last-mile distribution, consumption, and disposal are typically fairly local activities, communities should follow the example of municipalities like Seattle—which collaborated with the food retailing sector to introduce biological-nutrient-based packaging to increase the purity of communal food waste streams. Community members could rapidly establish local pilot applications of collaborative cross-sector participation to further provide tangible proof of concept and important test beds for debugging and refining circular setups prior to national/international rollouts. Activities among small and medium-sized businesses in local clusters (e.g., the machining cluster in Southern Germany, and chemical clusters in central Europe) could represent similar starting grounds for community-based activities.

Leverage your individual and collective market clout. As the case examples have shown, there are many nascent ideas on how to innovate and serve users better in the future with new offerings based on circular economic business models. Individuals, companies, and customers can now fast-track adoption by exercising their right of choice to demand, take up, and—jointly with the provider—continually improve products and services. Why not ask for a lease-based or performance-based model when you next consider purchasing furniture for home or office, restocking machinery assets or vehicle fleet, upgrading IT and the communications system, or expanding and adjusting a building portfolio? Governments can lend the full weight of their collective purchasing power to supporting circularity initiatives and de-risking the critical initial phase for pioneers of the circular arena.

Build matchmaker businesses and profit from arbitrage. As laid out in the report, there is plenty of low-hanging fruit for the first movers in adopting circular setups at a profit. For example, Turntoo's 'market maker' business model aims to facilitate new relationships between the producers of material-based products (such as lighting systems) and users simply interested in performance (in this case, light hours) to establish a simple method for determining prices that gives both the users and the suppliers an incentive. They are capitalising on the new transparency of the web and eroding transaction costs. This business model not only provides Turntoo with a profit stream but also boosts circular business.

Moving away from wasteful material consumption patterns could prove to be the start of a wave of innovation no less powerful than that of the renewable energy sector. It offers new prospects to economies in search of sources of growth and future employment. At the same time, it is a source of resilience and stability in a more volatile world.
Its inception will likely follow a 'creative destruction' pattern and create winners and losers. As well as long-term benefits, the circular economy also offers immediate opportunities that are waiting to be seized.

The concept of a 'closed-loop' economy has intrigued academics, designers, and marketers alike. The intellectual appeal of the concept might be related to the tangibility of the natural systems analogy or to its reframing power in a world dominated by the linear supply chain paradigm. Or it might owe its appeal to the fact that it links the debate around employment and growth with that around resource security and sustainability. In fact, it offers a promising avenue for corporate leaders to escape the perennial trade-off between growth and resource protection.

The data and the case examples presented do indeed indicate that the circular economy—if executed—promises to reconcile prosperity and sustainability and to overcome these inherited trade-offs. The report, however, also identifies the significant gaps in our current understanding. The concrete GDP and employment effects per sector and region are the more obvious knowledge gaps. Both of these topics will be the subject of further study and analysis by EMF and its partners.

One element of the circular economy, however, seems largely undisputed: It helps to minimise the economic impact of resource scarcity. In light of history's most dramatic resource demand shock and emerging signs of scarcity, improving the productivity of materials and natural resources is a crucial competitive response at company level and self-preserving reflex at market level. For these reasons, governments and companies have started looking at the circular model not only as a hedge against resource scarcity but also as an engine for innovation and growth. This report suggests that this opportunity is real and is opening a rewarding new terrain for pioneering enterprises and institutions.

This report is, however, just the start of a mobilisation process—we intend to go deeper into different products and sectors, assess the business opportunity in more detail, identify roadblocks and provide the tools to overcome them, and understand the macroeconomic effects in more depth.

The Ellen MacArthur Foundation

The Ellen MacArthur Foundation is committed to identifying, convening, and motivating the pioneers of the circular economy. The Foundation provides the fact base and study repository, shares best practices and excites and educates the next generation. In this way, it helps to bring down the barriers and create the leadership and momentum that this bold vision deserves.

'Even if you do not believe in a sustainability agenda, the efficiency gains of managing (circular) material flows should convince you to go after this potential.'
National Grid

'We're proud to be a founding partner of the Ellen MacArthur Foundation because we believe that the circular economy offers a solid concept on which we can base our thinking for our potential future business model. Resource scarcity is a real issue for any business and the threats outlined in this report are very real. Whilst we are only in the very early stages of exploring what we can do to move us towards circular models, our initial exploration confirms that this thinking could have substantial potential but would undoubtedly require us to extend our thinking beyond our current core competencies.'
B&Q

'While not every product is appropriate for refurbishment, it seems highly likely that nearly all big companies will have parts of their product portfolio where circular business practices will prove profitable.'
Cisco

'Waiting for industry-wide coordination will not work. But as there is so much low-hanging potential already at company level, why wait? There is substantial first-mover advantage, especially if you are open to take back materials/products from your competitors.'
Desso

'Nothing is impossible, particularly if it is inevitable'
Herman Mulder
Chairman of the Global Reporting Initiative

Appendix

Value drivers and assumptions of our in-depth product analysis

The objective of our in-depth case studies was not to explore technical or theoretical maxima, but to validate that—with small changes to the 'status quo' in terms of technology, design, and reverse-cycle capabilities—circular business models could produce attractive economic returns at product level. The results we observed across different products, picked from different sectors, provided us with orders of magnitude that we could use to scale up our results, first at the level of the market for a specific product (as outlined in the 'The Circulatory Calculator' sidebar in Chapter 3), then at the EU economy level across a specific portion of the manufacturing sector (see 'Examining the benefits EU-wide' in Chapter 4) and, finally, in the case of steel/iron ore, at a global resource level, also described in Chapter 4 under the heading, 'Mitigation of price volatility and supply risks'. Our intent was to validate that adopting circular business models would a) bring changes that are substantial and worth pursuing and b) drive lasting structural shifts (e.g., in terms of shifting material demand and usage run rates, as illustrated in Chapter 2 in: 'Long-term effects of circularity on material stocks and mix').

The following section, which is intended to help elucidate the mechanics of our analysis, comprises a high-level value driver tree, a compendium of the core assumptions regarding input values and likely improvement levers, the resulting outputs of our in-depth diagnostics at cost item level, and descriptions of the assumptions we make about what a circular system would entail in terms of collection and reverse treatment rates for each of the products we examine.

The value driver tree in Figure 24 depicts the architecture of our model. Figure 25 outlines specific input parameters and underlying assumptions regarding collection and reverse treatment rates. Figures 26 to 30 provide detailed information on the product-level economics of primary production and circular activities.

The output of the driver tree is an estimate of net material cost savings, as a percentage of total input costs, in the market for a specific product. Comparing this measure across several products gives us a range for relative net material savings potential—which we then consider in order to estimate the collective impact on our selected manufacturing sectors at the EU level.

In order to understand the effects of all specific treatment options, we explicitly chose products with different opportunities for reverse-cycle treatment. This allowed us to cover all types of circular setups in depth.

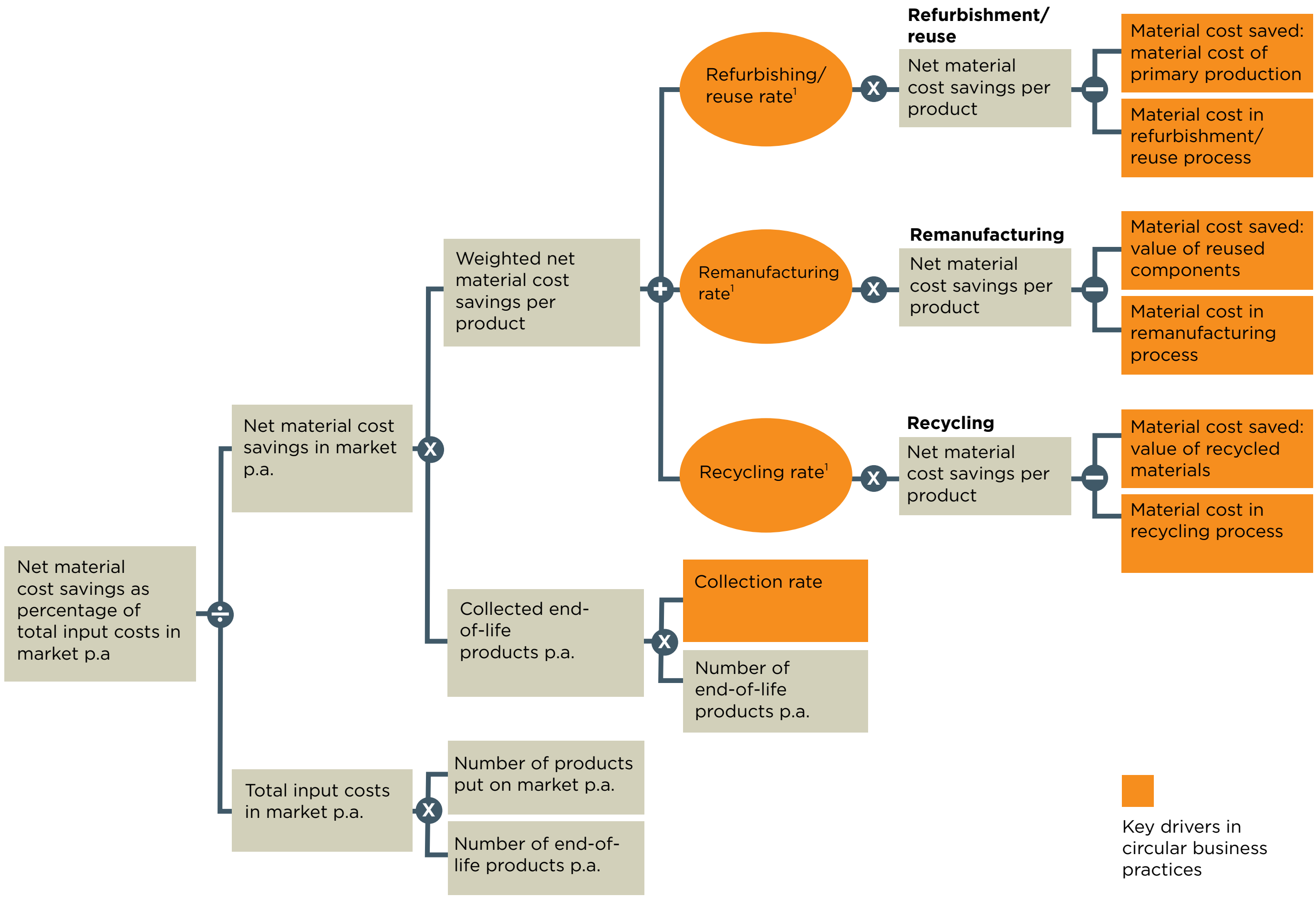
As we constrained the adoption of circular treatment processes (i.e., reuse, refurbishment, remanufacturing) to certain limits in the 'transition' and 'advanced' scenarios, we used recycling as the alternative treatment option for any products that were collected at end of life but not reused, refurbished, or remanufactured. The overall collection rate, then, limits the total amount of products treated along the reverse cycle. We assume that products not collected are landfilled—so, with exception of the cascading case examples in the biological nutrient section in Chapter 3, we do not assume additional benefits from waste-to-energy processes.

While we assumed an aggressive collection rate in the 'advanced scenario', we left this rate shy of 100% in order to account for some losses; similarly, we assumed only one product cycle, where for some products multiple cycles might be possible—and would presumably heighten the economic benefits of circularity; finally, we factored out the possibility of substantial material or product innovations that could potentially lead to much improved longevity of products or higher preservation of material quality. The 'advanced scenario' only attempts to capture the effect of a high structural proliferation of the circular economy in terms of collection rates and reverse treatment rates, while allowing further leakage, which will be unavoidable (given the second law of thermodynamics, i.e., the dissipation towards entropy).

In order to ground our analysis in current realities, we conducted extensive market-level research through interviews with relevant partners from industry and academia. Our objective was to ensure that the assumed improvement levers from the linear 'status quo' towards the circular 'transition' or 'advanced' scenario are individually technically feasible, commercially viable, and collectively sufficient to describe a consistent new circular operating model.

Appendix

FIGURE 24 **Driver tree: Factors affecting net material cost savings as a percentage of total input costs**



1 Rates as percentage of collected products; add up to 100%
SOURCE: Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 25 **Scenarios for more collection and circular treatment rates in Europe**

	Scenario	End-of-life products million p.a.	Collected Percent	Reused Percent[1]	Refurbished Percent[1]	Remanu-factured Percent[1]	Recycled Percent[1]	Components and business model, transition and advanced scenario
Mobile phone	Status quo	190	15	38	–	–	62	• Improved circular capabilities (products designed for disassembly, firms improve reverse-cycle skills)[2] enable higher remanufacturing rates in transition • Deposit, leasing and buy-back systems push collection rates closer to proposed EU 2016 target of 65% in transition, and beyond that in the advanced scenario • Industry-wide efforts establish comprehensive collection and treatment systems in advanced scenario
	Transition	190	50	38	–	41	21	
	Advanced	190	95	50	–	50	0	
Smartphone (B2B)	Status quo	13	20	–	38	–	62	• Improved circular capabilities (modular design and material choice)[2] foster refurbishment in transition • B2B buy-back systems and software for wiping user data push collection closer to proposed EU 2016 target of 65% in transition (beyond that in advanced scenario) • Joint vendor-supplier reverse supply chains, intra-firm alignment and regulation further increase collection rates in advanced scenario
	Transition	13	50	–	60	–	40	
	Advanced	13	95	–	50	–	50	
Light commercial vehicle[3]	Status quo	1.5	86	–	0	–	100	• Improved circular capabilities (products designed for disassembly, firms improve reverse-cycle skills)[2] enable higher refurbishment in transition scenario • Warranty offerings and proactive marketing measures reduce customer concerns about refurbished products • OEM/sector initiatives promoting circular production R&D foster refurbishment in the advanced scenario
	Transition	1.5	86	–	30	–	70	
	Advanced	1.5	86	–	50	–	50	
Washing machine	Status quo	2.3[4]	40	–	10	–	90	• Improved circular capabilities (pooled, OEM-centric circular activities)[2] boost refurbishment in transition • Transparent 'win-win' leasing contracts result in increased collection, controlled by manufacturers • Specialised intermediaries enable alternative ownership models on larger scale in advanced scenario
	Transition	2.3[4]	65	–	50	–	50	
	Advanced	2.3[4]	95	–	50	–	50	

1 Rates as % of collected products; add up to 100%
2 See detailed description in figures 27 to 30
3 Collection and treatment rates based on end-of-life products
4 Refers only to selected premium segment of washing machine market; total end-of-life washing machines would amount to ~20 million p.a.

SOURCE: Gartner statistics on mobile device sales, February 2011; Yankee statistics on mobile device sales, September 2011; U.S. Environmental Protection Agency (EPA), Electronics Waste Management in the United States Through 2009, EPA working paper, May 2011; Eurostat, WEEE key statistics and data, 2011; Jaco Huisman et al., 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment – Final Report, United Nations University working paper, August 2007; Georg Mehlhart er al., European second-hand car market analysis, Öko-Institut working paper, February 2011; Eurostat, ELV waste database, 2011; Eurostat, WEEE key statistics and data, 2011; CECED, Joint position paper on WEEE recast second reading, CECED position paper, July 2011; Euromonitor, houshold appliances statistics, 2011; Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 26 **Overview of selected products—prices and costs in linear production**

	Mobile phone[1]		Smartphone[1]		Light commercial vehicle[1]		Washing machine[1]	
	USD	Percent	USD	Percent	USD	Percent	USD	Percent
Price[2]	36	100%	400	100%	41,400	100%	970	100%
Input costs[3]	27	75%	228	57%	39,730	96%	832	86%
Material	16	44%	128	32%	22,760	55%	437	45%
Labour	2	6%	29	7%	4,140	10%	223	23%
Energy	2	6%	2	1%	680	2%	18	2%
Other[4]	7	19%	69	17%	12,150	29%	155	16%

1 Data is a standardised composite blend of 3 to 7 products
2 Excluding VAT and retail margin
3 Costs in final production; energy and labour costs in upstream activities partially embedded in material
4 Other includes SG&A; also includes R&D costs for light commercial vehicles

SOURCE: Credit Suisse, 'Smartphone report', broker report, August 2009; Bloomberg financial data; Pranshu Singhal, Integrated product policy pilot project, stage I final report: life cycle environmental issues of mobile phones, Nokia report, April 2005; Ina Rüdenauer et al., Eco-Efficiency Analysis of Washing Machines, Öko-Institut working paper, November 2005; Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 27 **Mobile phones: Economics of circular business activities**

USD per product[1], status quo and transition scenario

	Reuse		Remanufacture		Recycle	
	Status quo	Transition	Status quo	Transition	Status quo	Transition
Recoverable value	**22.8**	**22.8**	**5.0**	**5.6**	**3.1**	**3.6**
Treatment costs						
Collection and transport	1.0	0.8	1.0	0.8	1.0	0.8
Buy-back	9.1	9.1	0.0	0.0	0.0	0.0
Screening	1.9	1.4	1.9	1.4	1.9	1.4
Activity specific process (disassembly or recycling)	0.0	0.0	3.5	1.0	0.2	0.2
Cleaning and quality	2.0	2.0	0.0	0.0	0.0	0.0
Other	2.6	2.6	0.0	0.0	0.0	0.0
Material costs	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Profit	**6.2**	**6.9**	**-1.4**	**2.5**	**0.1**	**1.2**
Net material cost savings	**16.0**	**16.0**	**7.0**	**7.6**	**3.1**	**3.6**
Improvements in product design and reverse cycle skills	• 130 seconds efficiency gains and yield improvement to 95% (from 70%) in disassembly process through standardised size of displays and cameras and clip hold assembly • Contributing to recycling yield improvement from 80% to 95% for metals, through standardised material choice and improved recycling technology (e.g., “pre-shredder” separation) • 60% time savings in pre-processing through semi-automated pre-processing (screening) • 25% cost savings in transportation through optimised collection point locations and bundled transport to processing facilities					

1 Basic mobile phones selling at USD 30 to 80 before VAT with average lifetimes of around 2.5 years

SOURCE: Roland Geyer and Vered Doctori Blass, ‘The economics of cell phone reuse and recycling’, International Journal of Advanced Manufacturing Technology, 2010, Volume 47, pp. 515-525; Joaquin Neira et al., End-of-Life Management of Cell Phones in the United States, dissertation University of California at Santa Barbara, April 2006; J. Quariguasi Frota Neto et al., ‘From closed-loop to sustainable supply chains: the WEEE case’, International Journal of Production Research, 2010, Volume 48, pp. 4463-4481; Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 28 **Smartphones: Economics of circular business activities**

USD per product[1], status quo and transition scenario

	Refurbish		Recycle	
	Status quo	Transition	Status quo	Transition
Recoverable value	**218.2**	**218.2**	**5.3**	**6.3**
Treatment costs				
Collection and transport	1.2	1.2	1.2	1.2
Buy back[2]	21.8	21.8	0.0	0.0
Screening	4.0	3.0	4.0	3.0
Activity specific process (refurbishment or recycling)	14.9	10.4	0.2	0.2
Cleaning and quality	1.2	1.2	0.0	0.0
Other[3]	25.1	25.1	0.0	0.0
Material costs	**45.1**	**42.9**	**0.0**	**0.0**
Profit	**126.7**	**112.6**	**0.0**	**2.0**
Net material cost savings	**83.0**	**85.0**	**5.3**	**6.3**
Improvements in product design and reverse cycle skills	• 50% cost reductions in refurbishment process (excluding material) through reduced use of adhesives, modular assembly in production phase • 20% less need to replace casing through more robust, high quality materials in production process • Contributing to recycling yield improvement from 80% to 95% for metals, through standardised material choice and improved recycling technology (e.g., “pre-shredder” separation) • 25% cost reductions in initial screening process through fault-tracking software			

1 B2B smartphones selling at USD 300 to 600 before VAT with average lifetimes of up to 3.5 years
2 Introduction of buy-back scheme is a lever to increase collection and refurbishment rates. On a strict product level it is associated with additional costs
3 Other includes remarketing and selling costs, which are driven by recoverable value

SOURCE: Credit Suisse, ‘Smartphone report’, broker report, August 2009; Bloomberg financial data; Roland Geyer and Vered Doctori Blass, ‘The economics of cell phone reuse and recycling’, International Journal of Advanced Manufacturing Technology, 2010, Volume 47, pp. 515-525; Joaquin Neira et al., End-of-Life Management of Cell Phones in the United States, dissertation University of California at Santa Barbara, April 2006; J. Quariguasi Frota Neto et al., ‘From closed-loop to sustainable supply chains: the WEEE case’, International Journal of Production Research, 2010, Volume 48, pp. 4463-4481; Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 29 **Light commercial vehicles: Economics of circular business activities**

USD per product[1], status quo and transition scenario

	Refurbish		Recycle	
	Status quo	Transition	Status quo	Transition
Recoverable value	**13,796**	**13,796**	**1,174**	**1,174**
Treatment costs				
Collection and transport[2]	0	426	0	0
Buy-back	7,366	7,366	0	0
Screening	13	0	13	13
Depollution	42	0	42	42
Activity specific process (refurbishment or recycling)	1,044	319[3]	472	472
Other[4]	2,070	2,070	0	0
Material costs	**4,150**	**2,448**	**0**	**0**
Profit	**-889**	**1,167**	**648**	**648**
Net material cost savings	**18,613**	**20,316**	**1,174**	**1,174**
Improvements in product design and reverse cycle skills	• 33% decrease in refurbishment time realised by - Engine modularisation, wider design of engine bay (increased accessibility of connection points such as screws and plugs), usage of quick fasteners - Process standardisation, workflow optimisation, and specialisation in dedicated refurbishing centers (would typically be located centrally within the OEM's dealership and service network) • 40% decrease in material cost for refurbishment as centrally located, OEM related refurbishing centers can source spare parts at reduced cost			

1 Representative light commercial vehicle with an average lifetime of around 8 years in the EU (500-700 thousand kilometres)
2 Collection and transport costs only in transition state for refurbishment as this includes the transport to centralised refurbishment facilities
3 Includes costs for screening and depollution
4 Other includes SG&A costs, which are driven by recoverable value

SOURCE: Georg Mehlhart er al., European second-hand car market analysis, Öko-Institut working paper, February 2011; Eurostat, ELV waste database, 2011; GHK, A study to examine the benefits of the End of Life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, reuse and recovery under the ELV Directive, GHK report, May 2006; Ellen MacArthur Foundation circular economy team

Appendix

FIGURE 30 **Washing machines: Economics of circular business activities**

USD per product[1], status quo and transition scenario

	Refurbish		Recycle	
	Status quo	Transition	Status quo	Transition
Recoverable value	**560**	**560**	**38**	**38**
Treatment costs				
Collection and transport	12	12	12	12
Activity specific process (refurbishment or recycling)	80	80	14	14
Other[2]	80	80	0	0
Material costs	**297**	**161**	**0**	**0**
Profit	**93**	**228**	**12**	**12**
Net material cost savings	**140**	**275**	**38**	**38**
Improvements in product design and reverse cycle skills	40% decrease in material cost for refurbishment through pooled (OEM centralised) circular activities, as spare parts would not be subject to high trade margins currently observed			

1 Premium washing machine selling above USD 900 before VAT with average lifetime of 10,000 washing cycles
2 Other includes SG&A and other operating expenses

SOURCE: Adrian Chapman et al., Remanufacturing in the U.K. – A snapshot of the U.K. remanufacturing industry; Centre for Remanufacturing & Reuse report, August 2010; Erik Sundin, Product and process design for successful remanufacturing, Linköping Studies in Science and Technology, Dissertation No. 906, 2004; Ina Rüdenauer and Carl-Otto Gensch, Eco-Efficiency Analysis of Washing Machines , Öko-Institut working paper, June 2008; Ellen MacArthur Foundation circular economy team

Experts consulted for the analysis and reporting

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Additionally, a number of experts and practitioners from various sectors (e.g., consumer goods and retail; financial sector; logistics; motor vehicles; other transport; public sector; radio, TV, and communication; textiles; waste management) have been interviewed.

List of figures

About The Ellen MacArthur Foundation

The Ellen MacArthur Foundation was established in 2010 with the aim of inspiring a generation to rethink, redesign, and build a positive future through the vision of a circular economy, and focuses on three areas to help accelerate the transition towards it.

Education—Curriculum development and in-service teacher training
Science, technology, engineering, maths, and design (STEM) are subjects that will be at the heart of any transition to a circular economy. Equally crucial will be the development of 'systems thinking'—the skill of understanding how individual activities interact within a bigger, interconnected world.

The Foundation is building a portfolio of stimulus resources to help develop these skills, supporting teachers and establishing a network of education delivery partners to enable scalable training and mentoring. A parallel development programme for Higher Education has been established with a focus on supporting European business and engineering institutions and linking them to best-practice business case studies around the world. Currently, the Foundation is working to pilot, trial, and disseminate a comprehensive education programme across the U.K. with a view to this being a flexible, scalable model for use around the world. For more information, please visit the Foundation's website www.ellenmacarthurfoundation.org.

Communication—The opportunity for a redesign revolution
The Foundation works to communicate the ideas and opportunities around a circular economy to key target audiences— educational institutions, business, and in the public sector— using creative and social media. It believes that focusing on designing a restorative model for the future offers a unique opportunity to engage an entire generation when fused with the ability to transfer knowledge, co-create ideas and connect people through digital media.

Business—Catalysing and connecting businesses
From its launch in September 2010, the Foundation has placed an importance on the real-world relevance to its charitable programmes. Working with leading businesses in key sectors of the economy provides a unique opportunity to make a difference. B&Q, BT, Cisco, National Grid and Renault have supported the setup and development of the new charity and continue to support its activities through a partnership programme. In addition to working together with the Foundation to develop strategy for a transition towards a circular economy business model, partners are also actively supporting the Foundation's work in education and communication.

In 2011, the Founding Partners supported 'Project ReDesign', a series of innovation challenge workshops with 17-to-18 year old students across the U.K. The students were asked to try their hand at designing products by intention to 'fit' within a system and were able to interview Partners as business experts in their respective sectors. Winning students have gone on to a series of internships within the businesses to learn more about real-world design solutions for a circular economy.

Cross-sector collaboration will accelerate transition. To encourage this, the Foundation has established a Knowledge Transfer Network for businesses, experts, consultants, and academics. To register your interest and get connected please visit www.thecirculareconomy.org

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Rethink the future

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