TOWARDS THE CIRCULAR ECONOMY

Economic and business rationale for an accelerated transition
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 Commissioner for the Environment
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&G 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 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 rethinking 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 macroeconomic consequences are of shifting at scale towards a restorative economy. In doing so, we reviewed about a dozen mainstream products reflecting various circular design concepts, undertook economic analysis for key resource-intensive business sectors, and interviewed more than 50 experts. 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 that of a user. This calls for a new contract between businesses and their consumers 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 the 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 cascading 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 pure circles’ 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 fibres are then recycled into the wool insulation for construction—in each case substituting for an inflow of virgin materials into the economy. Similarly, cobbled fibres are safely returned to the biosphere.

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.

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.

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

2 Savings described are net of the recoveries associated during circular production processes, but they are gross of labour and energy costs. In each case, we measured, energy costs, and other non-costs of savings, as well as 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 by rising and less predictable prices in resource markets on the one hand and high economies-of-scale 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-intensive business sectors, and interviewed more than 50 experts. 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 that of a user. This calls for a new contract between businesses and their consumers 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.

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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 range 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 revenue’ 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 product revenue from 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 lost and the more material is preserved’. In a circular economy, by contrast, 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 in profits. Over a 20-year period, during 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 CO2e 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:

- **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 which 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 at 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—or a recurrent 3 to 3.5% 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
Executive summary

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 leapfrog 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. So, 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 consumer—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.

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.

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.

5. The shift has begun—‘Mainstreaming’ the circular economy

Our economy is currently locked into a system where production economics and contracts to regulation and mindsets favour the linear model of production and consumption. Yet, 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 is prepared to prefer access over ownership. This can be seen in the increase of shared cars,4 machinery, and even news articles of daily use. In a related vein, social networks have increased the levels of transparency and consumers’ ability to collaborate, technology, or regulation.

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.
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.
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 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 rise 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. Price volatility is 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 design and intention. 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 reclaimable 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 (less than 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 2 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 prosperity will trigger a surge of demand both larger and in a shorter time period than the world has 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.⁷

The current ‘take-make-dispose’ model entails significant resource losses and 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 ‘externals’. 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 stages 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 transportation (exacerbated by ever-longer global supply chains), losses during storage and at the retailer’s due to food surpassing its sell-by 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, most of those that occur in large, fairly homogeneous volumes. A recent UNEP report,¹⁰ for example, notes that only around

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⁴ McKinsey Global Institute, Resource revolution: Meeting the world’s energy, materials, food, and water needs (November 2011) report.
⁷ The linear and steady state 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: Meeting the world’s energy, materials, food, and water needs (November 2011) report.
⁸ Materialsflows.net

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**FIGURE 1** Global resource extraction is expected to grow to 82 billion tonnes in 2020

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<td>Fossil energy carriers</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Biomass</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>81</td>
</tr>
</tbody>
</table>

---

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, i.e., material used to generate energy and other material used in the production process.

² Drawn from 2010 OECD figures and the OECD:Collection scenario for 2020.

³ SOURCES: OECD; Ecoinvent (2007); 1992 Worldwatch Project, Britain’s futurist, October 2011.
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). 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 aluminum products (‘semis’), for instance, the processes of refining, smelting, and casting bauble into semi-finished aluminum account for 80% of the energy consumed (and 67% of the total costs incurred). 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 aluminum industry and its customers have been quite relentless in pursuing high recycling rates (according to UNEP, end-of-life recycling rates for aluminum 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%). 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—and the reduction of post-consumer food waste 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. 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. 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. 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). Higher prices for commodities, most notably oil and food, are in the headlines—from the record-breaking USD 447/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 markets. Simultaneously dramatic price increases 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

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**FIGURE 3**

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

<table>
<thead>
<tr>
<th>C&amp;D waste as a share of total</th>
<th>End-of-life treatment of C&amp;D waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C&amp;D as a significant waste stream</strong></td>
<td><strong>Less than one-third is currently recovered</strong></td>
</tr>
<tr>
<td>100% = 615 mln tonnes</td>
<td>100% = 662 mln tonnes</td>
</tr>
<tr>
<td>Recycled or reused</td>
<td>Discarded</td>
</tr>
<tr>
<td>20%</td>
<td>70%</td>
</tr>
<tr>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>A lot of the discarded material could be recovered</td>
<td></td>
</tr>
<tr>
<td>100% = 186 mln tonnes</td>
<td></td>
</tr>
<tr>
<td>Potential applications</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>14%</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>10%</td>
</tr>
<tr>
<td>Concrete/rock/bricks</td>
<td>11%</td>
</tr>
<tr>
<td>Soil/Free</td>
<td>11%</td>
</tr>
<tr>
<td>Reuse of soil after treatment</td>
<td></td>
</tr>
<tr>
<td>Ash products</td>
<td>14%</td>
</tr>
<tr>
<td>Road building material</td>
<td></td>
</tr>
<tr>
<td>Lumbar</td>
<td>40%</td>
</tr>
<tr>
<td>Wood flooring construction material</td>
<td></td>
</tr>
</tbody>
</table>

**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

11 U.S. Geological Survey; Minerals Information Database
12 Losses are calculated based on expected recovered resource of 2010 metal production, assuming today’s recycling rates remaining constant until end of life of a product. Calculations are based on recoverable volumes under current recyclability guidelines. Analyzed with today’s market prices for secondary materials, given monetary loss.
14 JFK database; WBMS; EAA; April 22, 2009
16 http://www.indexmundi.com/commodities/
17 M. E. D. Pezzulo et al., Millennium Ecosystem Assessment: Current State & Trends Assessment, 2006
18 W. | |
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).  

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. 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. 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. 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:

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. 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. 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. 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.

Infrastructure needs. Besides more infrastructure for a larger population, the world will 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—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 all the more pressing for agriculture in advanced economies, many of which are much closer to the technological limit and already producing near their maximum potential yields.

Political risks. Recent history shows the impact political events can have on commodity supply. There are numerous historical examples of how 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. Some commodities are particularly vulnerable: nearly half the new projects to develop copper reserves, for instance, are in countries with high political risk. Perhaps more shockingly, roughly 80% of all available arable land on earth lies in areas affected 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.
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. 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.

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.

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.
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—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; aiming for a ‘restorative’ and ‘regenerative’ society, in which ‘restorative’ implies making things, New York: North Point Press, 2002

Cradle: remaking the way we make things, New York: North Point Press, 2002

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

39 Emphasis added by the author. The success of its implementation is contingent on the degree to which the system is changed as a whole, and the relationship of the whole to its parts. The term ‘ecosystem’ is used here to encompass regenerative conditions rather than the more traditional one of the ‘ecological system’. Michael Braungart describes how ecosystems are self-regulating and self-regulating systems that can be used to design products and processes, and that as such are more resilient in the face of environmental change.

As a result, the circular economy draws a sharp distinction between the consumption and reuse 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. 29

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 to link the communication 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 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 is the key distinction of more circular business models; it would also make sure that we are putting the efficiency pressure on the right side: labour, which 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 that 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 focus on 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 mechanical 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 these 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
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 reintroducing 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.

2. From linear to circular

Continued

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

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.

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

Biological nutrients
Restoration
Biogas
Anaerobic digestion/composting
Energy recovery
Collection
User
Maintenance
Recycle
Product manufacturer
Parts manufacturer
Service provider
Landfill
Biorefinery/subassembly
Biosphere
Composting
digestion/
Anaerobic digestion
Cascades
Feedstock
Biochemical feedstock
Technical nutrients
Biorefinery
Mining/materials manufacturing
Hunting and fishing
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

• 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. Biochemicals from biomass include water used as a cooling medium or in process technology.

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.
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 center that is now named after Lyle, 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 Marrow for Grit. His model puts a particular emphasis on precisely defining the molecular composition of materials—including what you have, which is the basis of every quality-based materials recycling system. In some cases, notably for technical products that are subject to frequent upgrades, durability is not the optimum strategy—in that instance, it is preferable to design products in a way that makes their disassembly and the recovery of their components easier, rather than 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. The object remains 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 Cliff 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’. Students are encouraged to invent a better solar cell is an example. She thinks of it as ‘innovation inspired by nature’. Biromimicry 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.
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 the 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 products 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 1986, 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. Copyers 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 2008, its market share grew from 15 to 23% and profit margins (EBIT) 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 2010 to 2013; Project Life Institute vehicle (http://www.projectlife.org.uk/ archive/case-studie/ caterpillar-caterpillar-products-group)
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 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 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).
2. From linear to circular

Continued

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 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.
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 ‘niche’ status and become relevant in the mainstream economy.44

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.

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.45 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,46 job creation at a local level,47 and better employment conditions and educational opportunities.48 As an illustration, Brian Milioti 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.49

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.50 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.51

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46 GDP contribution based on Eurostat Input/Output tables 2007 for EU-27 economies
47 48 49 Frank Regan, Rochester bigideasforjobs.org/
50 Brian Milioti, Building Materials in a Green Economy: Community-Based Strategies for Dematerialization, 2010
51 Brian Milioti, Building Materials in a Green Economy: Community-Based Strategies for Dematerialization, 2010
52 53 54 Brian Milioti, Building Materials in a Green Economy: Community-Based Strategies for Dematerialization, 2010
55 56 57 Brian Milioti, Building Materials in a Green Economy: Community-Based Strategies for Dematerialization, 2010
58 59 60 Brian Milioti, Building Materials in a Green Economy: Community-Based Strategies for Dematerialization, 2010
61 As an illustration, Brian Milioti 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.
3. How it works up close

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 and associated costs 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 10 to 20 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. As a result, in mature markets (Western Europe, North America, Japan) consumers own 1.1 mobile phones on average, and the average usage time is down to less than 2.5 years.10 In emerging markets, the sector is nevertheless still poised for growth.11

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 few years, total WEEE volumes in the EU-27 are expected to grow cumulatively by more than 10%.12 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 of the 60 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.13

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 36.14 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 earth15 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.16

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 be changed 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).17 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 and 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.
3. How it works up close

Continued

FIGURE 11A
Mobile phones: Reuse and remanufacturing as a viable alternative to recycling
End-of-life product flows based on 2010 EU figures
Percentage of total end-of-life devices

### Status quo
- Collection
- Maintenance
- Unaccounted and landfill
- Parts manufacturer
- Product manufacturer
- Service provider

### Transition scenario
- Collection
- Maintenance
- Scrap material
- Service provider

### Remanufacture
- Remanufacture
- Reuse

### Recycle
- Recycle

#### Notes
1. Remanufacturing here refers to the reuse of certain components and the recycling of residual materials.
2. Costs for the entire disassembly process could be reduced by USD 3.5 per phone; an additional USD 0.8 per phone could be saved in collection and transport; as well as in the initial screening process.
3. Metal recycling leads to reduced energy consumption in the extraction phase, but it is implicitly considered in the material value of recycled metals, not in energy cost savings.

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-
3. How it works up close

Continued

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 CO₂e 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.

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

<table>
<thead>
<tr>
<th>USD per device</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status quo</strong></td>
</tr>
<tr>
<td><strong>Value improvement</strong></td>
</tr>
<tr>
<td><strong>Reuse</strong></td>
</tr>
<tr>
<td><strong>Remanufacture</strong></td>
</tr>
<tr>
<td><strong>Recycle materials</strong></td>
</tr>
</tbody>
</table>

| **Value improvement** | **Cost improvement** | **Net benefit** |
| **Treatment** | **Status quo** | **Circular** | **Treatment** | **process** | **Net benefit** |
| **Recyclable** | **10.0** | **2.6** | **6.4** | **1.7** | **3.7** |
| **Imitation** | **2.6** | **0.9** | **0.7** | **0.6** | **1.3** |

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

SOURCE: Ecoreview; Smartphones report, August 2009; Neto & Bloemhoff-Ruward (2009); Neira et al. (2006); Geyer & Doctori Blass (2008); EPA; Umicore; Remanufacture; Metal Bulletin; recyclecellula.com; amazon.com; recyclemobilephones.co.uk; Ellen MacArthur Foundation circular economy team

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### 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. 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.

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 potential 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 embodied raw materials is similar for both products.

### Refurbishment in the business-to-business (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 organisng 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, 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

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. Separately, the inclusion of fault-tracking software—that is, software systems that identify which parts of
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 could amount to more than EUR 350 million per year. Such a system would also save an estimated 100 thousand tonnes of CO2 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 15% of the total amount the smartphone industry spends on inputs.

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 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 of vehicles at the end of their final usage period (deregistration) are already as high as 71%, partially due to stringent EU directives, shifting volumes from recycling to refurbishing—as outlined in the transition scenario—can still save substantial material inputs by roughly USD 8.8 billion (i.e., 15% of material budget) annually (Figure 12A).
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 today’s mid-life vehicles.75 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.

An economic opportunity with benefits for the material balance. The industry average for domestic washing machines is 250 cycles a year.76 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 low-end machines cost 27 cents per cycle. We can also show that the cost incurred by an average household using one high-end machine over a 20-year period is lower than if the same household uses a series of low-end machines to do the same number of washes over the same period.77

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 yields almost 180 kg of steel savings and more than 2.5 tonnes of CO₂ 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.78

Providing updating and upgrading washing machine programmes after the first sale can thus be an effective 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 during 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 470 (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.79

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),80 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...
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 environmental 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 higher net present values, the probability to recover substantial profit, 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 collected82 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 margins 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 refurbishment has been a particularly interesting opportunity. In a situation where circular activities would be pooled and their net material cost savings could be further supported by collaborative treatment, third-party financing 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 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 hotels or laundromats. After 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 companies, 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 worked or not, manufacturers typically cite the following concerns:

Total cost of ownership (TCO) will increase. Current washing machine manufacturers cite the potential problem that customers will prefer to participate to the continuous efficiency gains in energy or water consumption offered by new washing machines. Therefore, the leasing 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 other 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 successful TCO for leasing 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., longer-lasting 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.
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 to 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. At power tools, end-of-life collection points could be set up in every store for a per-store investment of ~USD 1500, 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 returnable, 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., construction of a new kitchen), which 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 ‘kit 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, paper products) 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, even 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, has 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 much of Sub-Saharan Africa and Asia is highly dependent on phosphate rock from North Africa/ Western Sahara, these countries were responsible for 67% of all the rock phosphate output on the market in 2005.87

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 constructing a more circular system conducts the necessary—and sometimes geo-politically challenging—ways to the necessity of taking 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 food and 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 11 billion if the food fraction that is now in the municipal...
Continued

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

**EUR/tone collected**—negative numbers indicate a cost

<table>
<thead>
<tr>
<th>Status quo</th>
<th>Transition scenario</th>
<th>Advanced scenario</th>
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<tbody>
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1. Can take both (used) harvested and post-consumer waste as input
2. Source: Ellen MacArthur Foundation circular economy team

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**FIGURE 14**

**Biological nutrients**

- **Restoration**: Revenues (compost) 0 0 10-25
- **Biogas**: Revenues 0 20 20
- **Anaerobic digestion/composting**: Costs (0) (30)-(50) (30)-(50)
- **Extraction of biochemical feedstock**: Costs (0) (0) (7)
- **Landfill/sewage**: Costs (80)-(130) (25) 0

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### Rethinking agricultural production systems

In natural ecosystems, essential nutrients such as nitrogen and phosphorus 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, 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.

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**TABLE 1**

<table>
<thead>
<tr>
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<th>Service provider/distributor</th>
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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 overall 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 price of phosphor at an estimated 2 to 8 times that of mined rock.41 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 December42—making the prospect of profitable sewage nutrient recovery suddenly much more realistic.43 Until that moment, combining low lifetime 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 the urine from faeces, ranging from the PeePoo bag that enables villagers to cut out the sludge phase altogether by separating the urine from faeces, ranging from the PeePoo bag that enables villagers to...
Harnessing innovation

Material and technological innovation is a core enabler for fast-tracking transformation from a linear to a circular economy. While many of the proposed alterations on the journey to a circular economy will be gradual, innovation could likely lead to 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, it is also conceivable to develop technologies (e.g., applying membrane technology) that allow for detergent recovery after consumption.

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.

95 See for instance technologies developed by Leeds University, Xeros, a University of Leeds spin-off (http://www.xeros.com) and Soligear Bioplastics (http://www.soligearbioplastics.com).
96 Tim Jackson, Material and technological innovation: a focus on the Blue Economy (Harmless Packaging) and the Canadian firm Ecoflex) to niche players such as Cyberpac (Harmless Packaging) and the Canadian firm Ecoflex (www.ecoflex.com).
97 「Blue Economy」initiative, several of which could also accelerate the migration towards a more circular economy.
98 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 recycle—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/aerobic 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

Building blocks of a circular economy—what’s needed to win

**FIGURE 15**

**EXAMPLES**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
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<th>D</th>
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<tbody>
<tr>
<td>Skills in circular product design and production</td>
<td>New business models</td>
<td>Skills in building cascades/ reverse cycle</td>
<td>Enables to improve cross-cycle and cross-sector performance</td>
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<td></td>
<td>1. Cross-cycle and cross-sector collaboration facilitating factors</td>
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<td>e.g., joint product development and infrastructure management through</td>
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<td>• IT-enabled transparency and information sharing</td>
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<td></td>
<td>• Common infrastructure systems</td>
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<td>• Industry standards</td>
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<td>• Aligned incentives</td>
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<td></td>
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<td></td>
<td>• Match-maker mechanisms</td>
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<td></td>
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<td></td>
<td>2. Favourable investment climate</td>
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<td></td>
<td>Availability of financing and risk management tools</td>
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<td>3. Rules of the game to quickly reach scale</td>
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<td>Regulation in the areas of accounting, taxation, customs tariffs, customer and corporate responsibility, certification, standardisation</td>
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<td>4. Education</td>
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<td></td>
<td></td>
<td>Awareness raising in general public and business community</td>
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<td>Integration of circular concepts in university curricula</td>
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**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 cycles, 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 necessary conditions 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 higher 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 alloy 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
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-level remanufacturing systems’, says Jean-Philippe Page, and range of potential applications—‘a so that one can easily look up the origin, needs to feed into well-developed company-Continued

3. How it works up close

• 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 Cliff 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 specialist packaging company, explains: ‘The uncertain investment environment currently restrains large retailers from investing in new technologies’. Governments can create further funding streams 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 investment in the UK’s transition to a green economy’ (including the waste sector), offering targeted financial interventions to overcome market failures such as risk aversion due to unfamiliarity to asymptomatics 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.

The in-depth analysis of the different products selected for in-depth study suggest, which is summarised in the appendix, the 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 will translate into opportunities at economy, company and user level.

<table>
<thead>
<tr>
<th>Building blocks of a circular economy</th>
<th>Examples</th>
<th>Light commercial vehicle (LCV)</th>
<th>Washing machine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> Product design</td>
<td>Mobile phone</td>
<td>Component standardisation</td>
<td>Efficiency gains in energy and water consumption drive economic obsolescence and limit lifetimes</td>
</tr>
<tr>
<td>From...</td>
<td>To...</td>
<td>Limited degree of modularisation (e.g., bolted connections in LCV engine bay)</td>
<td>Regular software updates and upgrades of electronics and sensor systems post sale</td>
</tr>
<tr>
<td><strong>B</strong> Business models</td>
<td></td>
<td>Deposit payment or leasing models</td>
<td>Warranty offered on refurbished vehicles</td>
</tr>
<tr>
<td>From...</td>
<td>To...</td>
<td>Customer concerns about quality of refurbished vehicles</td>
<td>Customer concerns about alternative business models</td>
</tr>
<tr>
<td><strong>C</strong> Reverse cycle skills</td>
<td></td>
<td>Sub-scale refurbishing facilities</td>
<td>Quality issues within inapprop</td>
</tr>
<tr>
<td>From...</td>
<td>To...</td>
<td>Centralised refurbishment plants with optimised workflows, allowing for economies of scale</td>
<td>iate collection channels</td>
</tr>
<tr>
<td><strong>D</strong> Cross-cycle and cross-sector collaboration</td>
<td></td>
<td>University curriculum for engineers still focused on linear system</td>
<td>Manufacturer-controlled collection, enabled by leasing models</td>
</tr>
<tr>
<td>From...</td>
<td>To...</td>
<td>OEM/sector initiatives to foster R&amp;D of circular production methods</td>
<td>Specialised intermediaries enable alternative ownership models on larger scale</td>
</tr>
</tbody>
</table>

![FIGURE 16 Transition to a circular economy: Examples of circular business model adoption](image-url)

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 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.
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 worldview 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 the 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

Examining the benefits EU-wide

Our case studies show the positive business impact of circular business models on a product level. In Chapter 4, 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). 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 product categories, which is highly variable and potentially a distorting factor in our analysis. 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 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 shampoo 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 lasting

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 830 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 material costs is realised 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 implement 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 market-intensive than advanced economies, and thus could expect even greater relative savings from circular business practices.101

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.110 From our case study analysis, circular business practices appear to be effective in both cases. The evidence shows that recycling, remanufacturing, and other strategies for recovery are already providing 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 iron ore demand.111 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.112 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 19)—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 positive employment benefits. The three main macroeconomic sectors—the primary sector (extraction), the secondary sector (manufacturing), and the tertiary sector...
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 implications of more innovation across an economy is 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 CO₂e 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, Report 20 (Information No. 3441), October 26, 2011, p. 75
108 Remanufacturing in the U.K.: A Landscape of the U.K. remanufacturing industry, Centre for Manufacturing and Reuse, August 2010

FIGURE 20

Employment effects vary across primary, secondary, and tertiary sectors of a circular economy
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? Foremost, products do eventually reach a physical limit, given the second law of thermodynamics.108 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 been used. 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 eventually—such as Patagonia commits to doing with 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 was 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).

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.

Financial/legal obsolescence. When the owner of a product is no longer able to use it or is not interested in it, products may be retired for accounting or legal liability reasons. Firms typically recompute 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.

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 UK 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.109 Any reverse logistics system relies on its scale. Scale really matters in the reverse loop, implying the need for a superior position for collection and remanufacturing operations and fetching better prices for sales of larger quantities, explains Craig Diken 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


![Image](https://example.com/fig22.png)

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

| Component | Original lifetime | Refurbishment | Expected residual lifetime of component at time of refurbishment | Replacement refurbishment
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<tr>
<td>Engine</td>
<td>1st replacement</td>
<td>2nd replacement</td>
<td>Expected residual lifetime of component</td>
<td>Replacement refurbishment</td>
</tr>
<tr>
<td>Suspension</td>
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<td>Gearbox</td>
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How would it work?

In Figure 22 we show a simplified example of a light commercial vehicle along which refurbishment helps to overcome a dynamic where ‘weakest-link’ components determine the end of a product’s life. One replacement refurbishment at the end of the vehicle’s lifetime can provide a return on investment in the replacement refurbishment operation.

Sources:

- Ellen MacArthur Foundation circular economy team
- Alphabetical list of products in the example is taken from the 2005 to 2010 Product-Life Institute website (http://www.alphabetical-list-of-products.com), an industry-supported organisation in the U.K. that include the distribution, refilling, repair and collection of vending machines.
4. An economic opportunity worth billions

Continued

are offering a sales platform for used and remanufactured 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 knowledge 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. This allows Caterpillar to provide the same warranty for ‘reman’ engines as for new products. Caterpillar has a process in place to make sure that components are disassembled from end-of-life vehicles and actively managing a flow of quality material along the car’s life cycle. It is not only 85% of the weight of a car that is recycled, but recycled content of its vehicles. ‘While 85% of vehicle weight is recycled, only 25% of the material input for new cars consists of recycled material,’ says Jean-Philippe Hermine at Renault Environnement. Furthermore, the firm’s CEO, Philippe Hermine at Renault Environnement. Furthermore, the firm’s CEO, says: ‘We need to achieve higher recycling yields at lower cost, resulting in rapid and sustained growth for recyclers. Similar technology could be applied to the process of taking back products for remanufacturing or 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 Environment. 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 ‘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 and pre-sorting schemes and therefore aims to achieve higher recycling yields at lower cost, resulting in rapid and sustained growth for recyclers. Similar technology could be applied to the process of taking back products for remanufacturing or 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 Environment. 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 ‘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 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’. The circular economy is creating a new ‘reverse’ sector

FIGURE 23

The circular economy is creating a new ‘reverse’ sector
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. Achieving a healthy transition would rely heavily on the financial services sector serving as a clearhouse for capital—helping parts of the economy with capital surpluses invest this money more productively.

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. Customers become ‘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 circularisation 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 operations.
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.

4. An economic opportunity worth billions
Continued

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.
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.16 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.17 Given their superior resource productivity (e.g., ‘Carrotmobs’), 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 now manage assets throughout 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—sustainably—from motivating consumer awareness to facilitating concrete action (e.g., ‘Carrotmobs’).

Our new ‘take-make-dispose’ society has a long way to go before it reaches the peak of destruction that it has today. This lock-in, however, is getting weaker in the wake of powerful disruptive trends that will shape the economy for years to come:

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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,18 to around 500,000 in the late 2000s.19 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.20 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.21 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 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 business. 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 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 pilot 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 materials 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 (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 perception from producers to consumers that today are not readily available. Whilst much of the ‘software’ for the transition such as cradle to cradle is in place, the economic performance 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’. Turnover 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
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 seven 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, Turnttoo’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 capacies 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 and 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—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 market 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 with its highly detrimental impact on 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 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 environment rules. In the last intrinsic 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. 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 circularity efforts. 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.213 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 noting that could 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 high 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 margings 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 Environment/Sita in order to provide access to a steady supply of components and materials.

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127. See also ‘Examining the benefits EU-wide’ and Figure 16
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 so 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.
**Figure 24** Driver tree: Factors affecting net material cost savings as a percentage of total input costs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>End-of-life products million p.a.</th>
<th>Collected Percent</th>
<th>Reused Percent</th>
<th>Refurbished Percent</th>
<th>Remanufactured Percent</th>
<th>Recycled Percent</th>
<th>Components and business model, transition and advanced scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobile phone</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status quo</td>
<td>190</td>
<td>15</td>
<td>38</td>
<td>–</td>
<td>–</td>
<td>62</td>
<td>Improved circular capabilities (products designed for disassembly, firms improve reverse-cycle skills) enable higher remanufacturing rates in transition</td>
</tr>
<tr>
<td>Transition</td>
<td>190</td>
<td>50</td>
<td>38</td>
<td>–</td>
<td>41</td>
<td>21</td>
<td>Deposit, leasing and buy-back systems push collection rates closer to proposed EU 2026 target of 65% in transition, and beyond that in the advanced scenario</td>
</tr>
<tr>
<td>Advanced</td>
<td>190</td>
<td>95</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>0</td>
<td>Industry-wide efforts establish comprehensive collection and treatment systems in advanced scenario</td>
</tr>
<tr>
<td><strong>Smartphone (B2B)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status quo</td>
<td>13</td>
<td>20</td>
<td>36</td>
<td>–</td>
<td>–</td>
<td>62</td>
<td>Improved circular capabilities (modular design and material choices) foster refurbishment in transition</td>
</tr>
<tr>
<td>Transition</td>
<td>13</td>
<td>50</td>
<td>60</td>
<td>–</td>
<td>40</td>
<td>50</td>
<td>Ibex buy-back systems and software for helping user data push collection closer to proposed EU 2026 target of 65% in transition (beyond that in advanced scenario)</td>
</tr>
<tr>
<td>Advanced</td>
<td>13</td>
<td>95</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>50</td>
<td>Joint vendor-supplier reverse supply chains, extra-firm alignment and regulation further increase collection rates in advanced scenario</td>
</tr>
<tr>
<td><strong>Light commercial vehicle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status quo</td>
<td>15</td>
<td>66</td>
<td>–</td>
<td>0</td>
<td>–</td>
<td>100</td>
<td>Improved circular capabilities (products designed for disassembly, firms improve reverse-cycle skills) enable higher remanufacturing in transition</td>
</tr>
<tr>
<td>Transition</td>
<td>15</td>
<td>66</td>
<td>–</td>
<td>30</td>
<td>–</td>
<td>70</td>
<td>Warranty offerings and proactive marketing measures reduce customer concerns about refurbished products</td>
</tr>
<tr>
<td>Advanced</td>
<td>15</td>
<td>66</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>Circular activity (ODR/leasing initiatives promoting circular production) leads to higher refurbishment in the advanced scenario</td>
</tr>
<tr>
<td><strong>Washing machine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status quo</td>
<td>2.3</td>
<td>40</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td>90</td>
<td>Improved circular capabilities (pooled, ODM-centric circular activity) leads to boost refurbishment in transition</td>
</tr>
<tr>
<td>Transition</td>
<td>2.3</td>
<td>65</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>Transparency in OTR leasing contracts result in increased collection, controlled by manufacturers</td>
</tr>
<tr>
<td>Advanced</td>
<td>2.3</td>
<td>95</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>Specialized intermediaries enable alternative ownership models on larger scale in advanced scenario</td>
</tr>
</tbody>
</table>

1 Rates as % of collected products; add up to 100% 
2 See detailed description in figures 27 to 30 
3 Refers only to selected premium segment of washing machine market; total end-of-life washing machines would amount to ~20 million p.a. 
4 Rates as percentage of collected products; add up to 100% 
5 See detailed description in figures 27 to 30 
6 Joint vendor-supplier reverse supply chains, controlled by manufacturers, remanufacturers and others 
7 Rates as % of collected products; add up to 100% 
8 See detailed description in figures 27 to 30 
9 Rates as % of collected products; add up to 100% 

**Source:** Ellen MacArthur Foundation circular economy team
### FIGURE 26: Overview of selected products—prices and costs in linear production

<table>
<thead>
<tr>
<th>Mobile phone¹</th>
<th>Smartphone²</th>
<th>Light commercial vehicle³</th>
<th>Washing machine⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>USD</td>
<td>Percent</td>
<td>USD</td>
<td>Percent</td>
</tr>
<tr>
<td>Price³</td>
<td>36</td>
<td>100%</td>
<td>400</td>
</tr>
<tr>
<td>Input costs²</td>
<td>27</td>
<td>75%</td>
<td>228</td>
</tr>
<tr>
<td>Material</td>
<td>16</td>
<td>44%</td>
<td>128</td>
</tr>
<tr>
<td>Labour</td>
<td>2</td>
<td>6%</td>
<td>29</td>
</tr>
<tr>
<td>Energy</td>
<td>2</td>
<td>6%</td>
<td>2</td>
</tr>
<tr>
<td>Other¹</td>
<td>7</td>
<td>19%</td>
<td>69</td>
</tr>
</tbody>
</table>

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  


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

<table>
<thead>
<tr>
<th>USD per product, status quo and transition scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recoverable value</strong></td>
</tr>
<tr>
<td><strong>Status quo</strong></td>
</tr>
<tr>
<td>22.8</td>
</tr>
<tr>
<td><strong>Treatment costs</strong></td>
</tr>
<tr>
<td>Collection and transport</td>
</tr>
<tr>
<td>Buy-back</td>
</tr>
<tr>
<td>Screening</td>
</tr>
<tr>
<td>Activity specific process (disassembly or recycling)</td>
</tr>
<tr>
<td>Cleaning and quality</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td><strong>Material costs</strong></td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
</tr>
<tr>
<td>6.2</td>
</tr>
<tr>
<td><strong>Net material cost savings</strong></td>
</tr>
<tr>
<td>16.0</td>
</tr>
</tbody>
</table>

**Improvements in product design and reverse cycle skills**  
• 150 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  

**Appendix**

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

<table>
<thead>
<tr>
<th>Recoverable value</th>
<th>Refurbish</th>
<th>Recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
<td>Transition</td>
</tr>
<tr>
<td><strong>Treatment costs</strong></td>
<td>128.2</td>
<td>128.2</td>
</tr>
<tr>
<td>Collection and transport</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Buy-back</td>
<td>21.8</td>
<td>21.8</td>
</tr>
<tr>
<td>Screaming</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Activity specific process (refurbishment or recycling)</td>
<td>14.9</td>
<td>10.4</td>
</tr>
<tr>
<td>Cleaning and quality</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Other</td>
<td>25.1</td>
<td>25.1</td>
</tr>
<tr>
<td><strong>Material costs</strong></td>
<td>45.1</td>
<td>42.9</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td>126.7</td>
<td>112.6</td>
</tr>
<tr>
<td><strong>Net material cost savings</strong></td>
<td>83.0</td>
<td>85.0</td>
</tr>
</tbody>
</table>

**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

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

<table>
<thead>
<tr>
<th>Recoverable value</th>
<th>Refurbish</th>
<th>Recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status quo</td>
<td>Transition</td>
</tr>
<tr>
<td><strong>Treatment costs</strong></td>
<td>13,796</td>
<td>13,796</td>
</tr>
<tr>
<td>Collection and transport</td>
<td>0</td>
<td>426</td>
</tr>
<tr>
<td>Buy-back</td>
<td>7,366</td>
<td>7,366</td>
</tr>
<tr>
<td>Screaming</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Depollution</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Activity specific process (refurbishment or recycling)</td>
<td>1,044</td>
<td>319</td>
</tr>
<tr>
<td>Other</td>
<td>2,070</td>
<td>2,070</td>
</tr>
<tr>
<td><strong>Material costs</strong></td>
<td>4,150</td>
<td>2,448</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td>-889</td>
<td>1,167</td>
</tr>
<tr>
<td><strong>Net material cost savings</strong></td>
<td>18,613</td>
<td>20,316</td>
</tr>
</tbody>
</table>

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

Experts consulted for the analysis and reporting

Corporate experts

B&Q
Matt Sexton
Director of Corporate Social Responsibility
Roy Miller
Sustainability Manager - Products

Caterpillar
Greg Felley
Vice President with responsibility for the Remanufacturing and Components division

Cisco
Neil Harris
Head of Sustainability, Europe
Ian Redfern
Development Director
Conrad Price
Product Manager Voice Technology Group

Alastair Borissow
General Manager EMEA Remarking
John Mallan
Product Environmental Sustainability Program Manager

Cyberpac
John Hensley
Founder
Claire Black
Sales & Production Manager

Desso
Stef Kranendijk
CEO
Rudi Daelmans
Sustainability Director

Foresight Group
Andrew Page
Partner

ISE Appliances
John Hopwood
Managing Director

Marks & Spencer
Carmel McQuaid
Climate Change Manager
Dr Mark Summer
Sustainable Raw Materials Specialist

National Grid
Steve Wallace
Head of Climate Change and Environment

Craig Dikeman
Director of Inventory Management & Investment Recovery

Marcus Stewart
Future Distribution Networks Manager

Roger Aspin
Head of Logistics

Renault
Jean-Philippe Hermine
VP Strategic Environmental Planning

Ricoh Europe
Olivier Vriesendorp
Director, Product Marketing

Zhanna Serdyukova
Environmental Sustainability Consultant
Yaasunor Naito
Manager, Environmental Management

OPAI
Douwe Jan Joustro
Managing Partner

Turntoo
Sabine Oberhuber
Managing Partner

Turntoo and RAU
Thomas Rau
Founder - Director - Architect

Vestas
Rob Sauven
Managing Director Vestas Technology UK Ltd

Academic experts

Advanced Sustainability LLP
Chris Tunpen
Founder and Senior Partner

Biomimicry 3.8
Chris Allen
CEO

Collaborative Consumption
Lauren Anderson
Innovation Director

EPEA
Michael Braungart & Douglas Muhlil
Representatives of the Academic Chair, Cradle to Cradle for Innovation and Quality Rotterdam School of Management, Erasmus University, as well as EPEA Internationale Umweltforschung

Product-Life Institute
Walter R. Stahel
Founder-Director

Rochester Institute of Technology
Nabil Z. Nasr
Assistant Provost for Academic Affairs & Director

University of Cambridge
Peter Guthrie OBE
Professor & Director for Sustainable Development and Head of the Centre for Sustainable Development

University of Surrey
International Society for Industrial Ecology

Roland Clift CBE, FREng
Professor of Environmental Technology and Founding Director of the Centre for Environmental Strategy

Executive Director

University of York
James Clark
Professor and Director of the Green Chemistry Centre of Excellence for Industry

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⁴ Premium washing machine selling above USD 900 before VAT and with average lifetime of 10,000 washing cycles

Status quo: Refurbish = 38, Recycle = 12

Transition: Refurbish = 128, Recycle = 12

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 and with average lifetime of 10,000 washing cycles
2 Other includes SG&A and other operating expenses

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

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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