ELLEN MACARTHUR FOUNDATION
Rethink the future

TOWARDS THE CIRCULAR ECONOMY

Economic and business rationale for an accelerated transition

Executive Summary

Founding Partners of the Ellen MacArthur Foundation

BT | CISCO
Working together

B&Q

nationalgrid

RENAULT

Acknowledgements

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

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

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

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

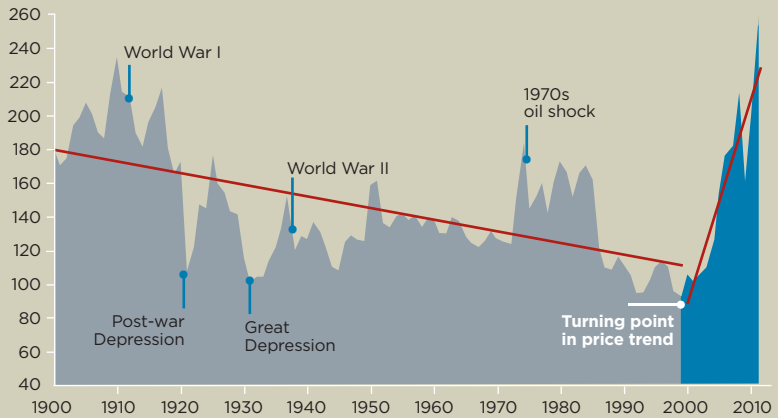
Executive summary

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

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

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

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



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

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

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

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

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. 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.

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

Recently, many companies have also begun to notice that this linear system increases their exposure to risks, most notably higher resource prices and supply disruptions. More and more businesses feel squeezed between rising and less predictable prices in resource markets on the one hand and high competition and stagnating demand for certain sectors on the other. The turn of the millennium marked the point when real prices of natural resources began to climb upwards, essentially erasing a century's worth of real price declines. 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. If no action is taken, high prices and volatility will likely be here to stay if growth is robust, populations grow and urbanise, and resource extraction costs continue to rise. With three billion new middle-class consumers expected to enter the market by 2030, price signals may not be strong or extensive enough to turn the situation around fast enough to meet this growth requirement. Against this backdrop, business leaders are in search of a 'better hedge' and an industrial model that decouples revenues from material input: the 'circular economy'.

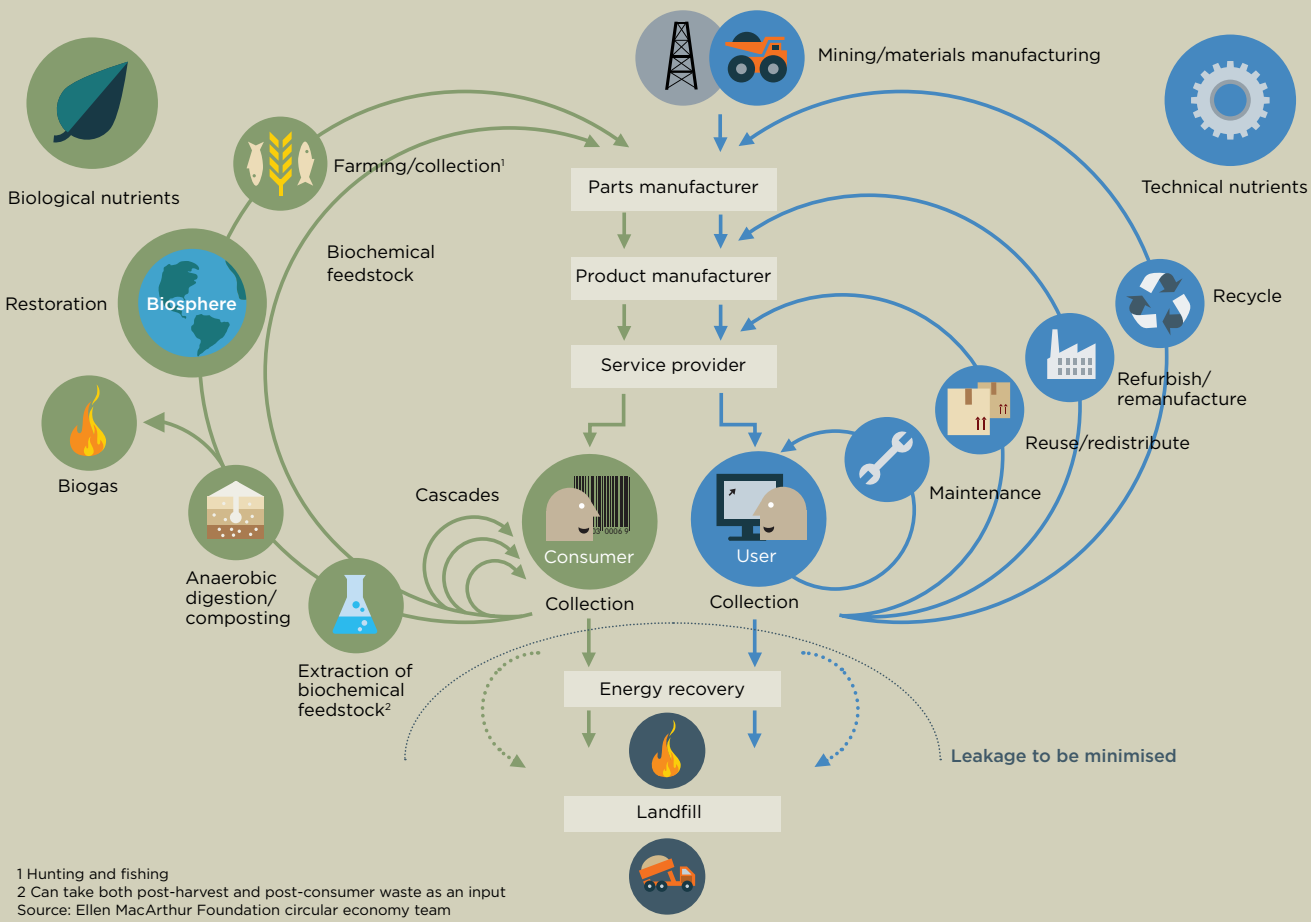
2. From linear to circular—Accelerating a proven concept

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

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

Executive summary
Continued

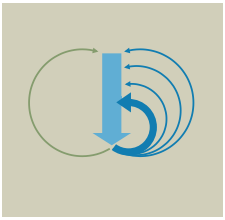
The circular economy—an industrial system that is restorative by design



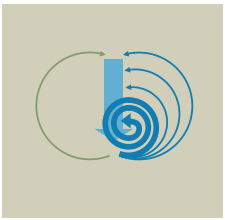
1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

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

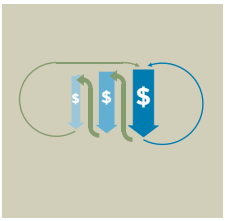
These principles all drive four clear-cut sources of value creation that offer arbitrage opportunities in comparison with linear product design and materials usage:



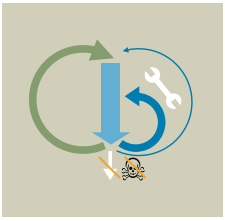
The **'power of the inner circle'** refers to minimising comparative material usage vis-à-vis the linear production system. The tighter the circle, i.e., the less a product has to be changed in reuse, refurbishment and remanufacturing and the faster it returns to use, the higher the potential savings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



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



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



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

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

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

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

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

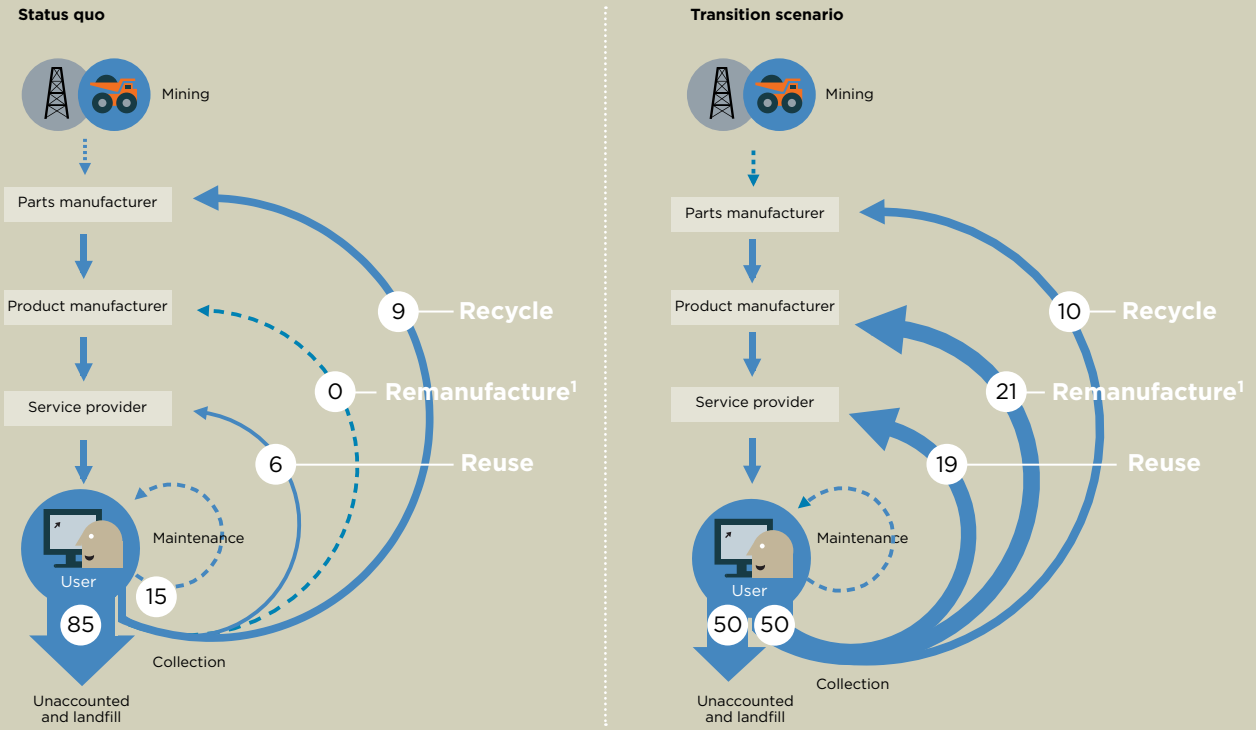
In order for companies to materialise the savings associated with a circular system by reusing resource inputs to the maximum degree, they need to increase the rate at which their products are collected and subsequently reused and/or their components/materials recuperated. Apart from the automotive industry, few industries currently achieve a collection rate of 25%. When shifting from linear to circular approaches, the rule of thumb for optimisation is: 'the tighter the reverse cycle, the less embedded energy and labour are lost and the more material is preserved'. Today's

Executive summary
Continued

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

ESTIMATES

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



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

recycling processes are typically 'loose' or long cycles that reduce material utility to its lowest 'nutrient' level. This is even more true for the incineration of waste. In a circular economy, by contrast, reverse activities in the circular economy will extend across an array of circles for repair and refurbishment of products, and remanufacturing of technical components. Likewise, the reverse chain for biological nutrients returns those back to the biosphere via composting and anaerobic digestion. Furthermore, reverse cycles will not only be confined within an industry but also 'cascaded' across different industries.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Executive summary
Continued

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

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

How economies win

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

Substantial net material savings. Based on detailed product level modelling, the report estimates that the circular economy represents a net material cost saving opportunity of USD 340 to 380 billion p.a. at EU level for a 'transition scenario' and USD 520 to 630 billion p.a. for an 'advanced scenario', in both cases net of the materials used in reverse-cycle activities. The latter would equate to 19 to 23% of current total input costs[3] or a recurrent 3 to 3.9% of 2010 EU GDP. Benefits in the advanced scenario are highest in the automotive sector (USD 170 to 200 billion p.a.), followed by machinery and equipment (USD 110 to 130 billion p.a.), and by electrical machinery (USD 75 to 90 billion p.a.). These numbers are indicative as they only cover 'sweet spot' sectors that represent a little less than half of GDP contribution of EU manufacturing sectors. They also assume the addition of only one product cycle with today's technologies. Yet many cycles would be possible and technological innovation could likely lead to rapid improvements and additional cost savings. However, these opportunities are clearly aspirational for now, and companies must make creative and bold moves, break out of the linear system, and ensure that the underlying arbitrage opportunities are robust over time.

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

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

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

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

The circular approach offers developed economies an avenue to resilient growth, a systemic answer to reducing dependency on resource markets, and a means to reduce exposure to resource price shocks as well as societal and environmental 'external' costs that are not picked up by companies. A circular economy would shift the economic balance away from energy-intensive materials and primary extraction. It would create a new sector dedicated to reverse cycle activities for reuse, refurbishing, remanufacturing, and recycling. At the same time, emerging market economies can benefit from the fact that they are not as 'locked-in' as advanced economies and have the chance to leap-

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

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

frog straight into establishing circular setups when building up their manufacturing-based sectors. Indeed, many emerging market economies are also more material intensive than typical advanced economies, and therefore could expect even greater relative savings from circular business models. So, the circular economy will have winners, and it is worth exploring the dynamics that the adoption of the circular economy will trigger.

How companies win

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

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

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

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

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

How consumers and users win

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

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

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

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

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

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

Our economy is currently locked into a system where everything from production economics and contracts to regulation and mindsets favours the linear model of production and consumption. However, this lock-in is weakening under the pressure of several powerful disruptive trends:

First, **resource scarcity and tighter environmental standards** are here to stay. Their effect will be to reward circular businesses over 'take-make-dispose' businesses. As National Grid explains: 'we are now analysing our supply chains systematically [for circularity potential]. The potential is bigger than we initially thought'.

Executive summary
Continued

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

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

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

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

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.

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