ELLEN MACARTHUR FOUNDATION
Rethink the future

2013

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TOWARDS THE CIRCULAR ECONOMY

Opportunities for the consumer goods sector

Pre-print version

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Foreword

A new term has emerged in recent years to describe our modern era—the Anthropocene. It rightly implies that in this age humans became the dominant force shaping our physical environment. It is evident that an economy that extracts resources at increasing rates without consideration for the environment in which it operates, without consideration for our natural planetary boundaries, cannot continue indefinitely. In a world of soon to be 9 billion consumers who are actively buying manufactured goods, this approach will hamper companies and undermine economies. We need a new way of doing business.

The concept of a circular economy promises a way out. Here products do not quickly become waste, but are reused to extract their maximum value before safely and productively returning to the biosphere. Most importantly for business leaders, such an economy can deliver growth. Innovative product designers and business leaders are already venturing into this space.

I don't believe business can be a mere bystander in the system that gives it life. This is why decoupling economic growth from environmental impact and increasing positive social outcomes are two priority objectives that lie at the heart of my vision for corporate strategy. Businesses need to reinvent themselves, and the circular economy framework provides very promising perspectives, as outlined in the present report.

I welcome this important contribution to the debate regarding the nature of 'economic things to come'. In 2012, the Ellen MacArthur Foundation report 'Towards the circular economy' contributed significantly to our understanding of the opportunity for durable goods. This year's report again takes the business point of view to explore the opportunity of the circular economy for fast-moving consumer goods. Building on all the academic work of recent years and a large base of industry examples, it establishes needed thought structures, identifies the major levers available, and calls out the economic opportunity.

I envision a 21st century where innovation, values, and sheer drive will help harness the power of regenerative processes, and this new report inspires our thinking on how to create prosperity that is not at the expense of tomorrow's opportunities.



Sincerely,
Paul Polman
Chief Executive Officer, Unilever

In support of the circular economy



'As a founding partner to the Ellen MacArthur Foundation, at Kingfisher and B&Q we are already taking steps towards circularity. This is particularly relevant for us in timber, where we are regenerating working woodlands and finding a second life for our waste wood. This report identifies the massive opportunities of circularity for business. Circularity supports our Net Positive approach to doing business—where we go beyond minimising our negative impact and instead design ourselves to have a positive one. We are very excited about the report's findings and are looking forward to continuing to work with the Foundation to understand how we unlock some of the commercial opportunities it highlights.'
B&Q Ian Cheshire, Kingfisher Group, Chief Executive



'We are working with key strategic suppliers to explore the commercial opportunities of the circular economy, which we believe to be significant. We are also integrating the principles of the circular economy into our product development process. As a founding partner of the Ellen MacArthur Foundation, we are delighted to support this latest report, which underlines the relevance and opportunities provided by the circular economy.'
BT Group Gavin Patterson, Chief Executive BT Retail



'The Circular Economy offers a profound transformational opportunity, which represents the interests of both the global community as well as the next generation. Transitioning towards a regenerative model will stimulate economic activity in the areas of product innovation, remanufacturing, and refurbishment, and in turn generate employment. However, organisations must now question their ability to flex and adapt, to innovate and develop new business models that exploit the way the market is moving. In today's increasingly complex, interdependent, and interconnected era, technology will play a critical role in helping us understand and manage our vital resources in order to build a genuinely sustainable economy.'
Cisco Chris Dedicoat, President, EMEA



'The Foundation's latest report builds on work we have done internally, highlighting the opportunities anaerobic digestion provides for producing renewable gas from waste. It gives new impetus to the work National Grid is doing around the circular economy with regards to the regeneration of major infrastructure assets, our ambition to use the circular economy as a core focus for innovation and sustainability across our organisation, and to the joint ambition National Grid and the Foundation have of inspiring a generation through our work in education.'
National Grid Steve Holliday, Chief Executive



'The EU's recent European Resource Efficiency Platform manifesto highlights the importance of decoupling future economic progress from resource constraints. Renault has been pursuing this objective for some time and is working closely with the Ellen MacArthur Foundation, applying circular processes, and shaping the future of mobility with electric vehicles—initiatives that will safeguard our leading role in the automotive sector. The new report brings added focus to this work, and we are delighted to have had a role in its elaboration.'
Renault Carlos Tavares, Chief Operating Officer for Renault

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Acknowledgements

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

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

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

Our special thanks go to the many leading academic, industry, and government agency experts who provided invaluable perspectives and expertise. A list of the contributors is included at the end of this report.

Report synopsis

In January 2012, the Ellen MacArthur Foundation launched a report on the business and economic rationale for a circular economy. Given the complexity of the topic, it offered an introduction to an alternative to the linear 'take – make – dispose' model of consumption. The report showed that this linear model is facing competition from a pattern of resource deployment that is circular by design: it creates much more value from each unit of resource by recovering and regenerating products and materials at the end of each service life. More specifically, it demonstrated that designing and using durable goods, such as cars and vans, washing machines, and mobile telephones, in accordance with circular principles offers materials savings in Europe that could be worth USD 380 billion in an initial transition period and up to USD 630 billion with full adoption.

This year, the Foundation has turned its focus to 'fast-moving' consumer goods, products that typically have a lower unit cost, are bought more often, and have a much shorter service life than durable goods. Fast-moving consumer goods currently account for 35 per cent of material inputs into the economy, a significant part of total consumer spending on tangible goods, and 75 per cent of municipal waste. Importantly, the consumer goods sector absorbs more than 90 per cent of our agricultural output—possibly our most embattled resource in the future.

If we are to move to a circular economy, it is therefore crucial to test how it applies to the consumer goods sector.

Chapter 1
Examining the success and limits of linear consumption and the power of the circular economy concept to break through the linear 'dead end'.

Chapter 2
Discussing how the principles of the circular economy apply to consumer goods—within both the biological and the technical spheres.

Chapter 3
Investigating how circular businesses can extract more value than the l inear economy in three parts of the consumer goods industry: making use of food waste and food processing by-products, reducing the material impact of apparel without reducing consumer choice, and getting to grips with beverage packaging.

Chapter 4
Describing the potential economic payoff of a rapid scale-up of circular business models in the consumer goods sector.

Chapter 5
Proposing concrete steps for participants in the consumer goods industry and for the public sector to bring the circular economy into the mainstream.

Executive summary

The last 150 years of industrial evolution have been dominated by a one-way or linear model of production and consumption in which goods are manufactured from raw materials, sold, used, and then discarded as waste. This model has been exceptionally successful in providing affordable products to consumers and material prosperity to billions. In developed economies, it has largely displaced a traditional economy that featured more reuse and regeneration but required more labour and produced lower returns on investment.

While there is still room for the linear model to expand geographically and realise even higher efficiencies, there are signs that the coming decades will require productivity gains and quality improvements at a new order of magnitude. As the global middle class more than doubles in size to nearly 5 billion by 2030, consumption and material intensity will rise accordingly, driving up input costs and price volatility at a time when access to new resource reserves is becoming more challenging and expensive. Perhaps most troubling is that this sudden surge in demand may have adverse effects on the environment that further constrain supply. Symptoms of these constraints are currently most visible in the food and water supply. Declines in soil fertility are already estimated to cost around USD 40 billion globally.

Modern circular and regenerative forms of consumption—so far limited to a few high-end categories—represent a promising alternative and are gaining ground. Powerful examples of their economic viability at scale exist today, from anaerobic digestion of household waste to apparel recovery. While these examples are still limited in geographical scope, we estimate the full potential of the circular economy to be as much as USD 700 billion in global consumer goods materials savings alone. Our product- and country-level analyses covered examples in product categories that represent 80 per cent of the total consumer goods market by value, namely food, beverages, textiles, and packaging. Highlights of opportunities for profitable businesses include the following:

• Household food waste. An income[1] stream of USD 1.5 billion[1] could be generated annually for municipalities and investors by collecting household food waste in the U.K. separately and processing it in line with circular principles to generate biogas and return nutrients to agricultural soils. If all countries in the EU matched Italy's high rates of separate collection of household food waste for biogas and compost production, the resulting income stream would give towns and cities a new source of revenue.

• Industrial beverage processing waste. An additional profit of USD 1.90 – 2.00 per hectolitre of beer produced could be created in Brazil on top of the margin for beer by selling the biggest waste product, brewer's spent grains, to farmers in the fish farming (specifically tilapia) and livestock sectors, thus 'cascading' it to another industry as a feed supplement. Cascaded uses are relevant for many food processing by-products.

• Textiles. A revenue of USD 1,975 per tonne of clothing collected could be generated in the U.K. if the garments were sold at current prices, with the gross profit of USD 1,295 comfortably outweighing the cost of USD 680 required to collect and sort each tonne. Like Italy in household food waste collection, the U.K. sets a standard worth emulating, with an average clothing collection rate of 65% of clothes discarded.

• Packaging. A cost reduction of 20 per cent from USD 29 to USD 24 per hectolitre of beer consumed would be possible in the U.K. by shifting from disposable to reusable glass beer bottles, which would lower the cost incurred for packaging, processing, and distribution. While durability would require a 34% increase in the amount of glass used per bottle, this increase in material would be dwarfed by the savings that accrue from being able to reuse such bottles up to 30 times, as currently achieved in Germany.

Over time, the market is likely to systematically reward companies with an edge in circular business practices and hence dramatically lower resource requirements. With new technologies in hand, they can win by scaling up the concept of the circular economy. There will also be rewards in rapidly urbanising countries where waste streams of

1 Includes revenue from feed-in-tariff in the U.K. and avoided landfill fees

nutrients, heat, partially treated wastewater or CO_2 can be converted back into high-value biological products or energy using much shorter and more resilient supply chains. The time to invest in building a circular economy is now.

1. The success—and limits—of linear consumption

Between 1900 and 2000, global GDP grew twenty times and created hitherto unknown levels of material prosperity. The availability of consumer goods of increasing quality and reliability at ever-lower cost was supported by new production technologies, globalised supply chains, fewer labour inputs, and what we call a 'linear' industrial economy. Within this linear model, resources are extracted from the earth for production and consumption on a one-way track with no plans for reuse or active regeneration of the natural systems from which they have been taken. In developed economies, the linear economy has largely displaced the traditional 'lower productivity' circular economy.

The linear economy is material and energy intensive; it relies on economies of scale, and typically builds on complex and international supply chains. All these supply chains have a common goal—the consumer. The goods an OECD citizen buys for consumption annually—800 kg of food and beverages, 120 kg of packaging, and 20 kg of new clothing and shoes—are, for the most part, not returned for any further economic use. In the current 'take-make-dispose' system, around 80 per cent of these materials will end up in incinerators, landfill or wastewater. They come to a dead end.

There is still room to expand the linear economy model geographically to the developing world, where labour and capital are not yet organised around agricultural or processing value chains optimised for efficiency. At the same time, there are growing signs that the power of the linear model is reaching a limit:

- In modern manufacturing processes, opportunities to increase efficiency still exist, but the gains are largely incremental and insufficient to generate real competitive advantage or differentiation.

- Manufacturers' margins are being compressed by slow growth in demand, increasing costs, and higher price volatility for resources.

- Agricultural productivity is growing more slowly than ever before, and soil fertility and even the nutritional value of foods are declining.

- The risks to food security and safety associated with long, 'hyper-optimised' global supply chains appear to be increasing.

For these reasons, alternative models for production, distribution, and consumption based on reusing resources and regenerating natural capital have caught the attention of businesses around the world. 'Circular' sources of value appear more transformational and less incremental than further efficiency improvements.

2. Rediscovering a circular model

For durables, the benefits of reuse have been widely demonstrated. For consumer goods—such as food and beverages or apparel and their packaging—which are short-lived and often transformed during use, the economic benefits of a circular design are more complex in origin and harder to assess.

We estimate the total material value of fast-moving consumer goods at USD 3.2 trillion. Currently, we recover an estimated 20 per cent of this material, largely through decomposition (cascading of waste and by-products through adjacent supply chains, returning nutrients to the soil, and recycling) and partly through reuse. In the future, we believe that a much higher share of consumer goods materials could potentially be recovered though reuse and decomposition. Even in the near term, without the dramatic application of bio-based products and the full redesign of supply chains, the value that can be recovered could be increased to 50 per cent.

Recovering part of the USD 2.6 trillion of material value lost today is a huge opportunity for fast-moving consumer goods companies. However, they face significant hurdles as they try to break out of the linear model. We need to build efficient collection

Executive summary
Continued

systems to capture the materials value of goods that are consumed far from their point of origin, design better combinations of goods and packaging, and dramatically increase the attention management gives to recovering value in the post-use stages of the supply chain. Enough thriving examples of circular business models already exist today to give us confidence that these challenges can be met.

3. Commercial opportunities today

In our product-level analysis, we have studied specific examples in product categories that represent 80 per cent of the total consumer goods market by value: food, beverages, textiles, and packaging. Circular opportunities exist all along the value chain: in manufacturing (food and beverages), in the distribution and consumption stages (textiles, packaging), and in post-use processing (food waste). Generally, in developing countries, more circular opportunities are lost at the manufacturing stage. In developed countries, losses are more heavily concentrated at the consumer level.

Food and beverages
There are profitable ways to deal with the mixed food waste discarded by households and the hospitality sector. In the U.K., processing this waste in line with circular principles could generate an income stream of USD 1.5 billion annually—providing a major economic opportunity for both municipalities and investors while generating biogas and returning nutrients to agricultural soils.

There is further potential for circularity in industrial food processing, where waste is mostly created as a by-product—such as brewer's spent grains in beer-making or orange peel in juice production. With beer—the world's third most-popular beverage after water and tea, and representative of foods and beverages that generate valuable processing by-products—keeping brewer's spent grains out of landfill. Instead, selling them as a feed supplement in accordance with circular principles, can create a profit of USD 1.90 per hectolitre of beer produced.

Clothing
There are profitable circular opportunities to reuse end-of-life clothing, which, in addition to being worn again, can also be cascaded down to other industries to make insulation or stuffing, or simply recycled into yarn to make fabrics that save virgin fibres. If sold at current prices in the U.K., a tonne of collected and sorted clothing can generate a revenue of USD 1,975, or a gross profit of USD 1,295 after subtracting the USD 680 required to collect and sort each tonne. We also see an opportunity in expanding the 'clothing-for-hire' segment to everyday clothes, as another offshoot of the asset-light trend.

Packaging
Recovery for reuse, keeping packaging in circulation longer, will deliver dramatically greater materials savings and profit than the traditional linear one-way system, especially if collection rates are high. Our modelling of beer containers shows that shifting to reusable glass bottles would lower the cost of packaging, processing, and distribution by approximately 20 per cent per hectolitre of beer consumed.

Recovery for decomposition is another option. End-of-life materials can be cycled back through one of two forms: either recycling the materials or returning nutrients to the soil via biodegradable packaging.

Recycling—This is a solution when it is not feasible to install reuse infrastructure, but significant materials savings are immediately available by collecting and recycling used packaging. In OECD countries, prices of raw materials already make it profitable today for collection and recycling companies to increase the volume and range of the different fractions recycled. Our case shows a profit of nearly USD 200 per tonne of plastic collected for recycling. In parallel, more thoughtful product design and material choices should also significantly improve recovery and regeneration solutions.

Biodegradable packaging—This is the solution of choice when single-use packaging can facilitate the return of bio-based materials (e.g., food) back to the soil, or when no other viable end-of-life option exists. Most available biodegradable materials are currently more expensive than traditional packaging, but

innovative solutions are being developed in specific applications and could allow the profitable evolution of biodegradable packaging.

Because they extract value from what are otherwise wasted resources, these and other examples of the modern circular economy are inherently more productive than linear business models. Technologies and regulatory solutions already exist to support businesses and investors in seizing such opportunities and changing consumption habits towards longer use and reuse. As Steve Sharp, executive director of marketing at Marks & Spencer, says: 'Not many years ago people would have been incredulous at the idea of routinely recycling bottles and plastic, yet this is now commonplace behaviour. We want to try to achieve that same shift of behaviour with our Shwopping campaign and make recycling clothes a habit'. M&S CEO Mark Bolland adds: 'We're leading a change in the way we all shop for clothing, forever.[2]'

4. Accounting for the business and economic benefits

The full value of these circular opportunities for fast-moving consumer goods could be as much as USD 700 billion per annum in material savings or a recurring 1.1 per cent of 2010 GDP, all net of materials used in the reverse-cycle processes (see Figure 20 in Chapter 4). Those materials savings would represent about 20 per cent of the materials input costs incurred by the consumer goods industry. In addition, we expect the following benefits:

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

• Land productivity and soil health. Land degradation costs an estimated USD 40 billion annually worldwide, without taking into account the hidden costs of increased fertiliser use, loss of biodiversity, and loss of unique landscapes. Higher land productivity, less waste in the food value chain, and the return of nutrients to the soil will enhance the value of land and soil as assets. The circular economy, by moving much more biological material through the anaerobic digestion or composting process and back into the soil, will reduce the need for replenishment with additional nutrients. This is the principle of regeneration at work.

• Job creation potential. A circular economy might bring greater local employment, especially in entry-level and semi-skilled jobs, which would address a serious issue facing the economies of developed countries.

This total prize is just the beginning of a much bigger set of transformative value-creation plays as the world scales up the new circular technologies and business models. We are likely to see a selective 'grafting' of new circular business models and technologies during this period of transition. Initially, these grafts may appear to be modest in their impact and play into niche markets (e.g., growing greenhouse tomatoes, hiring out high-end fashion items). But over the next 15 years these new business models will likely gain an increasing competitive advantage, because they inherently create much more value from each unit of resource. In addition, they are likely to meet other market requirements, associated with more secure supply, more convenience for consumers, and lower environmental costs.

In a world of 9 or 10 billion consumers with fierce competition for resources, market forces are likely to favour those models that best combine specialised knowledge and cross-sector collaboration to create the most value per unit of resource over those models that simply rely on ever more resource extraction and throughput. Natural selection will likely favour the agile hybrids—able to quickly combine circularity with scale—that are best adapted to a planet transformed by humanity.

By 2030, the prize could be much more than USD 700 billion—and we expect to see circular business models accounting for a large part of the global bio-value chains. In that not-so-distant world, investors, managers, and regulators will be talking about how companies get going and start

2 http://platform-online.net/2012/10/ms-unveil-first-shwopping-garment/

Executive summary
Continued

learning how to hybridise their business models—for markets that will be worth well over USD 25 trillion.

5. The shift has begun—mainstreaming the circular economy

Why now? Our economy currently seems locked into a system in which everything from production economics and contracts to regulation and the way people behave 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 that extract value from wasted resources over take-make-dispose businesses. Second, information technology is now so advanced that it can trace materials anywhere in the supply chain, identify products and material fractions, and track product status during use. Third, we are in the midst of a pervasive shift in consumer behaviour: a new generation of consumers seems prepared to prefer access over ownership.

Capturing the new opportunities will require leading corporations and municipal authorities to develop a new set of 'circular' muscles and capabilities along their traditional supply chains. These new capabilities will be reinforced by a set of fundamental developments in resource markets, technology and information systems, and consumer preferences:

• Urbanisation that centralises flows of consumer goods and waste streams

• A set of new technologies (e.g., anaerobic digestion) that enables dramatic improvements in the way value is extracted from today's biological waste streams as well as opportunities to combine multiple waste streams (CO_2, heat, wastewater, nutrients) into advanced agro-manufacturing systems

• New IT capabilities that support more precise management and tracking and tracing of biological flows in the system (e.g., RFID chips that provide detailed information about product spoilage rates)
• Emergence of online retail channels that redefine the way value chains work in distribution, waste recovery, and consumer choice without increasing material impact

• New business models that improve control over scarce resources and 'assetise' them for reuse in value-maximising transfers as feedstock to subsequent industrial or agricultural processes

• A new model of collaborative consumerism —in which consumers embrace services that enable them to access products on demand rather than owning them—and collaborative consumption models that provide more interaction between consumers, retailers, and manufacturers (e.g., performance-for-pay models, rent or leasing schemes, return and reuse)

• New packaging technologies and systems that extend food life and minimise packaging waste.

Companies are successfully building more circular business models in and for the consumer goods industry, and we see new roles and vantage points emerging:

• *Volume aggregators:* Markets for residues and by-products are currently severely under developed, creating arbitrage opportunities for volume aggregators who stand at the forefront of organising these markets. Asos, an aspiring online 'fashion destination' that offers more than 850 brands of new clothes, has extended its scope to the reverse cycle by creating a parallel platform where consumers can resell end-of-life clothing, and small firms can market 'vintage' garments and accessories as well as new ones. More specialised companies offer sales platforms in the business-to-business environment, too, such as the Waste Producer Exchange (WPE) in the U.K., which supports users in selling waste products and materials.

• *Technology pioneers:* New technologies, (such as PHA bioplastics production from industrial wastewater) offer technology leaders a vast array of opportunities. A recent rush of private equity capital into recycling and circular technology may signal the first influx of semi-permanent settlers on this frontier. Veolia has pioneered the production of bioplastics from sludge. Wastewater

treatment systems today often use bacteria that eat sludge and neutralise it into carbon. Using proprietary technology, Veolia achieved a breakthrough in converting this 'wastewater carbon' into biomass rich in PHA, which has mechanical properties equivalent to polypropylene and is thus valuable in making consumer plastics and chemicals. Veolia produced the first biopolymers from municipal waste in 2011, and is now refining the process to meet end-customer specifications at full-scale wastewater treatment sites in Belgium and Sweden.

• *Micro-marketeers:* In the food and beverage industry, large retailers such as Woolworths in Australia, WholeFoods in the U.S., and Migros in Switzerland, as well as global food giants such as Unilever, Nestlé, Danone, and Kraft Foods, are preparing for markets with more local sourcing, distributed manufacturing, increased customer interaction, diversified customer demand, multi-channel purchasing (including home-delivery), and ultimately more intimate customer relationships. At the same time, low-cost same-day delivery services allow local brick-and-mortar companies to compete with national brands online, further propelled by the emergence of online 'hyper-local' advertising platforms that allow people to find such businesses in their neighbourhood. Serving these micro-markets at scale and developing an integrated 'systems' offering that links products, ordering, delivery, and aftersales service could be the name of the game, and could even feature 'assisted' self-production by the consumer. In such a strategy, the circular economy could become a major source of differentiation—if not an obligation. Micro-marketeers could proactively offer B2B service contracts, develop blueprints for 'zero-waste' plants, or establish food waste reuse centres.

• *Urban-loop providers:* Urbanisation in emerging economies will create urban and peri-urban systems where waste streams of nutrients, heat, partially treated wastewater, or CO_2 are converted back into high-value biological products using much shorter and more resilient supply chains than today. Urban-loop economies offer a playing field for businesses with sophisticated know-how in design, engineering, and infrastructure operations. An example of this is The Plant, Chicago, a vertical aquaponic farm growing tilapia and vegetables that also serves as an incubator for craft food businesses and operates an anaerobic digester and a combined heat and power plant. Discarded materials from one business are used as a resource for another in an explicitly circular system.

• *Product-to-service converters:* In the textile industry, players like Patagonia—which pioneered the 'Common Threads Initiative' to reduce the environmental footprint of its garments—seek longer and more intimate customer relationships beyond the point of sale. Value-added offerings like repair, amendment, return and leasing offer much greater customer interaction at multiple touchpoints. Some players are beginning to redefine themselves as fashion or style partners with superior customer insights and value opportunities along the life cycle and across different categories.

We do not know how the shift will come about. It would come slowly or in a sudden sweep, as a reaction to external shocks. It may be the outcome of stirring public stimuli ('man on the moon') or of a killer application, as a silent manufacturing revolution. It could even emerge as grassroots consumer activism, or as voluntary, inclusive industry commitment. History has seen all of these patterns lead to breakthroughs: we do not know which of them will tip consumption into a more regenerative mode. We do expect, however, that the shift will play out between pioneering industry leaders, discriminating, well-informed consumers, and forward-looking public constituencies.

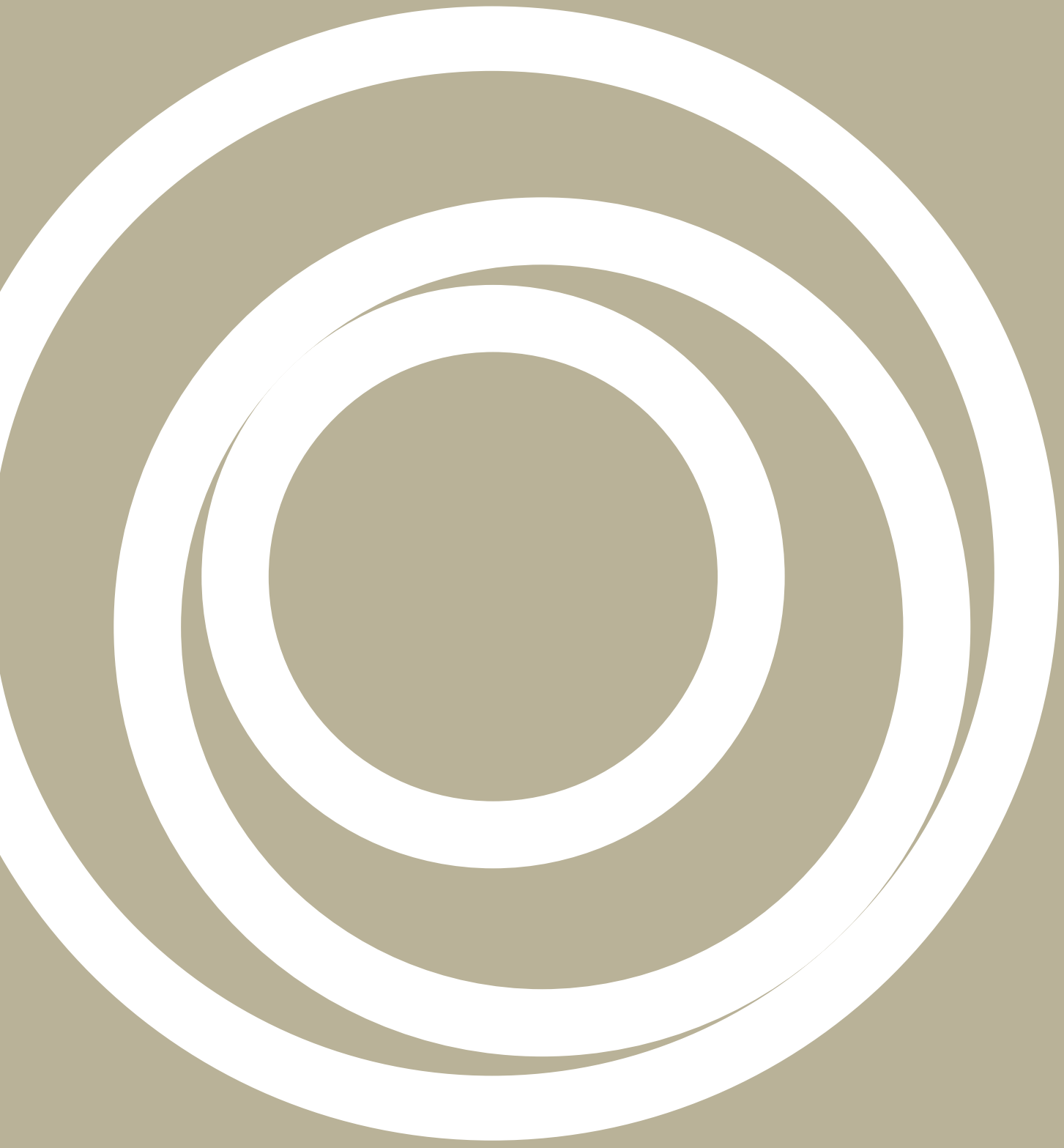
Executive summary
Continued

To support collaboration and knowledge transfer between companies engaged in implementing circular economy solutions, the Ellen MacArthur Foundation has created the Circular Economy 100, an invitational global platform for 100 pioneering businesses to accelerate the transition to a circular economy over a 1,000-day innovation period. The CE100 supports its members via a number of enabling initiatives, including: an online library of best practices, insights and learnings, acceleration workshops, an annual summit to showcase solutions and leading thinking, network and partnership opportunities with other CE100 members and universities, and executive education.

The limits of linear consumption

1

Examining the success and limits of linear consumption and the power of the circular economy concept to break through the linear ‘dead end’.



1. The limits of linear consumption

With around USD 12 trillion in annual sales[3], the fast-moving consumer goods industry is a force to reckon with in the global economy. While expenditure levels for such goods are vastly different across the globe, they represent a significant share of household budgets in both developed and emerging markets[4]. The influence of the sector stretches beyond its financial impact: it takes in approximately USD 3 trillion worth of materials[5] and is responsible for the vast majority (75%) of municipal solid waste[6]. It also drives a large share of losses in virgin forests due to the conversion of land for agricultural use, one of the key supply sectors for the packaged goods industry[7]. If we are to move to a circular economy, it is therefore critical for us to address consumer products head on.

We're sitting on a consumption time bomb

The material impact of the consumer goods industry is set to rise exponentially, driven by a growing middle class in emerging markets: three billion additional consumers in the next 20 years, with a higher propensity to buy manufactured goods (Figure 1). This will be driven by the following factors:

- Far more consumers. The OECD estimates that the global middle class will increase from 1.9 billion in 2009 to 4.9 billion in 2030 with almost 90% of the growth coming from the Asia-Pacific region[8].

- Much higher consumption. The advent of disposable incomes to many more households means that a large number of consumers will move from 'doing without' to enjoying the benefits of their improved financial position by buying more items. Consumption in emerging markets is expected to rise to USD 30 trillion per year by 2025, up from USD 12 trillion in 2010. The rise in disposable income is in part dependent on the health of the global economy, and prospects for sustained growth in the linear economy may be limited by resource constraints.

- Higher material intensity. In addition, these new consumers will switch from loose, unbranded products to manufactured goods. The material impact of such packaged goods is much greater, both because of processing losses and packaging.

As a result, consumer demand from emerging economies has the potential to exponentially increase the use of materials, bring about dramatic rises in input costs, and result in hard-to- manage commodity volatility. In the face of unprecedented resource demands, radical resource efficiency will no longer suffice. Efficiency can lower the amount of energy and materials used per dollar of GDP, but fails to decouple the consumption and degradation of resources from economic growth. This calls for system level redesign. The circular economy provides a model which, if implemented correctly, would go much further than minimising waste. Effective cycling of the many materials our society discards would enable us to rebuild our natural assets—soil and soil quality in particular—so crucial to continued prosperity.

Circular patterns vary over time and geography

Historically, consumer industries operated using more circular principles. A large proportion of food was grown locally, bought loose and prepared in the home, without further processing. Packaging was generally owned by the consumer, and almost entirely reused, while apparel would be repeatedly repaired and reused, and often passed down through generations. A larger share of edible food would be consumed (e.g., vegetables with slight blemishes); unavoidable food waste would be cycled for use in animal feed. Human and animal waste was seen as a valuable resource and cycled, typically back onto the land and sometimes their chemical value would be extracted, such as in tanning and dyeing processes.

In short, the idea that 'waste equals food' was very much part of all aspects of daily life. While Western countries have largely abandoned such systems and habits, much of consumption in the developing world still functions using a more circular model, with far more active cycling of discarded materials, especially food waste, much higher penetration of reusable packaging, a high proportion of food bought loose (e.g., vegetables from markets) or in bulk, and much more livestock/crop integration in small-scale/ subsistence farming.

3 Euromonitor 2012

4 Approximately 23%-28% in USA (U.S. Bureau of Labor Statistics) and 52%-64% in China (China national statistics yearbook)

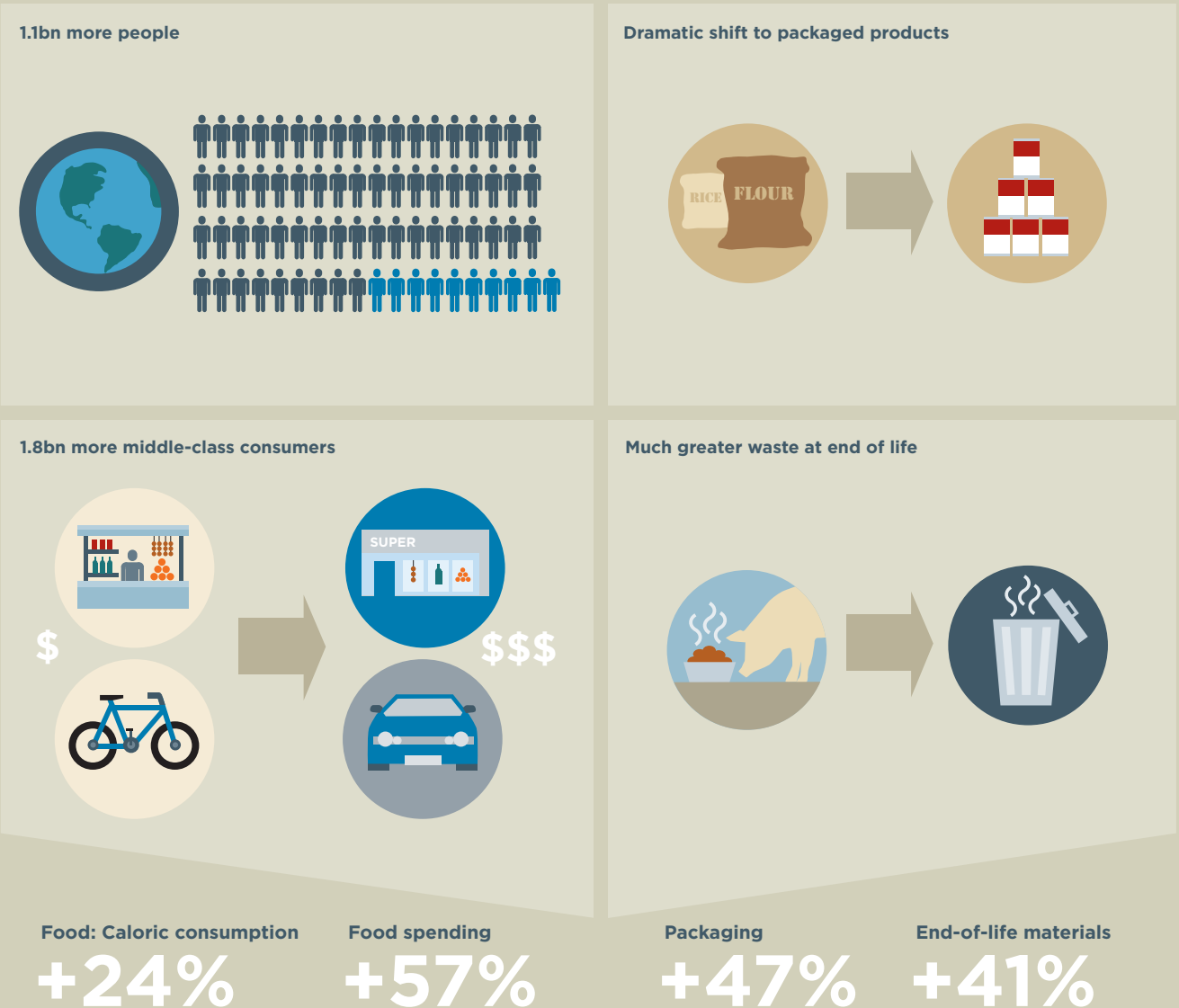
5 Euromonitor 2012, expert interviews

6 US EPA 2010

7 TEEB: Mainstreaming the economics of nature—a synthesis of the approach, conclusions and recommendations of TEEB; 2010

8 Perspectives on Global Development 2012, Social cohesion in a shifting world. OECD

FIGURE 1 **A potential consumption time bomb**[1]
2010-2025



1 Estimate based on the comparison of low-income countries or population segment (e.g., India) and middle/high income countries and segments (e.g., US)
SOURCE: World Bank. Ellen MacArthur Foundation circular economy team

1. The limits of linear consumption
Continued

The consumer goods industry—locked in a linear paradigm?

A key insight in circular economy thinking is the division between biological and technical materials. Biological 'nutrients' (cf. Braungart & McDonough) are designed to re-enter the biosphere safely for decomposition to become valuable feedstock for a new cycle—i.e., 'waste equals food'. These products are designed by intention to literally be consumed or metabolised by the economy and regenerate new resource value. Technical 'nutrients' are materials that either do not degrade easily or cause contamination within the biological nutrient flow. These durable materials and products are designed by intention to retain embedded quality and energy.

At first glance, it might appear harder to adopt circular principles in the consumer industry than in the durable goods sector, given some of its intrinsic characteristics. Consumption in reality mostly means 'destruction' and the loss of potentially valuable products, components, and materials—and their associated embedded energy and restorative value.

In addition to this, adoption of circular approaches in the consumer goods industry is complicated by four factors:

- **Large volumes in broad distribution.** Fast-moving consumer goods (or 'consumer packaged goods') are characterised by high throughput volumes, are bought frequently, represent a large physical volume (in developed countries, for example, consumers buy almost a tonne worth of consumer goods per year, including packaging),[9] and come at relatively low prices (i.e., each purchase is individually quite cheap). Large quantities of packaged goods typically end up widely dispersed, rendering them more difficult to recover economically, unlike mobile phones or cars.

- **Product lifespan.** Most fast-moving consumer goods have a short to very short lifespan. Some product categories are literally consumed, such as food, beverages, cosmetics, and paper tissues, meaning they are no longer fit for use after first use. Other categories are used for only a relatively short time, or just a few times. This is obviously very different from the relatively expensive durable consumer and business-to-business products, where use is measured in multiple years, and where the case for reconditioning, repair or recovery of the value inherent in the products is more obvious.

- **Packaging component.** Consumer goods generally contain two components: the product itself, and its packaging (part of which is usually discarded immediately the product is used). The impact of producing and discarding materials is significant for both product and packaging, so we need to explore solutions for each.

- **Multi-staged value chain.** Consumer products are created, sourced and used via a global value chain, starting with raw agricultural and chemical inputs. These go through a manufacturing process, a complex distribution and retail chain, use by consumers, and waste collection, before typically ending their lives in landfill, sewage or incineration. Importantly, manufacturers, retailers and waste handlers are usually separate parties (unlike in some durable categories such as automotive), and frequently have misaligned or competing interests. This means that to create successful new circular models, we need to assess their impact on profitability for manufacturing, retail/distribution, and waste handling.

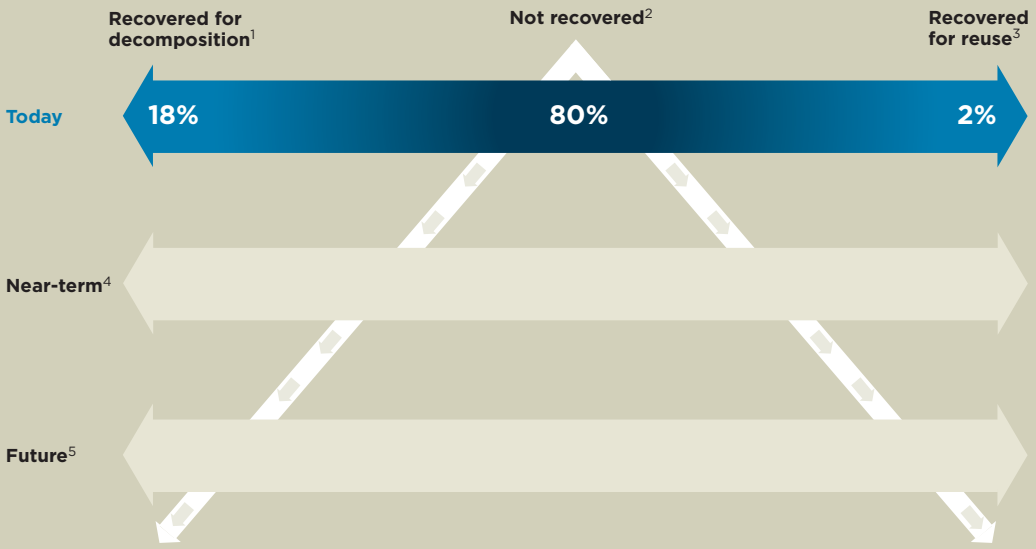
Waste as part of the linear system results in economic losses on all fronts

Declining real resource prices (especially fossil fuels) have been the engine of economic growth in advanced economies throughout most of the last century[10]. The low level of resource prices relative to labour costs has also created the current wasteful system of resource use. Reusing biological and technical materials has not been a major economic priority given the ease of obtaining new input materials and cheaply disposing of refuse. As Jamie Lawrence, Senior Sustainability Advisor Forest and Timber at Kingfisher, points out, access to virgin wood and fibre has been so easy in the past that reusing fibre was never on the industry's agenda. In fact, the biggest economic efficiency gains have resulted from

9 EPA, Euromonitor 2012, US Economic Research Service, IRI, Veronis Suhler Stevenson, Winery and Distillery Waste Management, Bloomberg, SRI, RISI, Let's Recycle, Knowaste, Eye See Mission, 'Waste: Uncovering the Global Food Scandal', Press search

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

FIGURE 2 **Path to a circular economy—design and recover consumer goods for reuse or decomposition**
% of FMCG products (by value)



1 Decomposition to allow materials to be recycled or biodegraded, depending on product/packaging material characteristics and end of life collection
2 Cannot be reused, recycled or biodegraded due to poor design and/or lack of end-of-life collection options
3 Reuse can include direct reuse for the same or different value streams or industries
3 Economic feasibility demonstrated in this report
4 Economic feasibility not yet proven

SOURCE: Euromonitor 2011, Expert interviews, Ellen MacArthur Foundation circular economy team

using more resources, especially energy, to reduce labour costs. Such a system had few difficulties delivering lower costs as long as the fiscal regimes and accounting rules that govern it allowed many indirect costs to remain unaccounted for—the externalities. A systems analysis, however, reveals losses throughout the value chain.

The picture is similar in the consumer goods sector. Globally, only 20% of FMCG products are currently recovered at the end of their useful life, largely through 'decomposition' in its broadest sense—the cascading of waste and by-products through adjacent supply chains, recycling of used products and packaging, and the return of nutrients to the soil (Figure 2). Very little reuse occurs today, partly, of course, because of the one-off nature of consumption, but also because of the preponderance of single-use packaging. The materials left unrecovered—landfilled, incinerated, or lost in waste water—can be observed all along the value chain, from production to post-consumption.

- **Value lost in agriculture.** A large share of inputs for the consumer goods production system originates in the agricultural supply chain. Losses of such material occur at several different steps in the production of crops and in animal husbandry : losses due to mechanical damage or spillage during harvest, animal death during breeding, or discards during fishing (globally this amounts to 8% of catches).[11] Crops sorted out post-harvest due to product specifications are another source of loss (especially true of fruits and vegetables in industrialised countries), as well as spillage or degradation during transport and storage, exacerbated by ever-longer global supply chains.

- **Value lost in processing.** In the production of consumer goods, significant volumes of materials are commonly lost during processing. The Food and Agriculture Organisation estimates that 8-12% of total food inputs are lost in the processing stage.[12] Such losses can either be due to the specific process (e.g., beer brewing inherently

11 FAO: Global Food Losses and Food Waste—Extent, causes and prevention, 2011

12 FAO: Global Food Losses and Food Waste—Extent, causes and prevention, 2011

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Continued

generates waste volumes, with 15-20% of input materials—including water—never making it into the final product[13]), accidental (process glitches and interruptions, for instance), or due to narrowly defined product specifications—where both incoming materials and processed output may be unduly discarded.

• **Value lost in distribution.** In low-income countries, fruit, vegetables, fish/seafood and dairy products suffer particularly heavy losses during post-harvest handing and distribution—often in the region of 10 - 20% of the input material.[14] Causes include food sales not meeting the sell-by date, being stored under the wrong conditions, or failing to meet tight retailer standards.

• **Value lost in use.** In medium- and high-income countries, a large proportion of products are not put to the use for which they were purchased. This applies especially to food (the average U.S. family throws away half the food they buy, worth USD 164 billion)[15] as well as to other consumer product categories. Cosmetics for example are frequently left unfinished. Many clothes are only worn a few times before being disposed of or forgotten. U.K. households for instance have around USD 50 billion worth of clothing in their wardrobes that has not been worn for a year.[16]

• **Value lost at end of life.** A large proportion of consumer goods are wasted at the end of their first use. Packaging, food waste and discarded textiles often end up in landfill where they have zero value; in fact, they attract additional costs for collection and disposal. Current recycling rates are significant for only a handful of waste types—mostly those that occur in large, fairly homogeneous volumes. Packaging is perhaps the most widely recognised source of waste.

• **Value lost in design.** Durability of design and durability required in use are often not well matched. Packaging, if used only once, should be designed for 'decomposition' and subsequent regeneration, whether through the biological sphere, or—if it can be isolated and processed easily and at extremely high levels of recovery— the technical sphere. Clothing today frequently does not reach its theoretical end of life at all because its use does not match the intent of its design.

Throughout the value chain, it is worth distinguishing between value losses that are unavoidable (bones left on the plate after consumption of meat or textile trimmings after cutting patterns have been optimised for yield), losses that are avoidable (dairy losses due to inadequate cold chains or purchased but unconsumed foodstuffs), and those that are likely avoidable. Examples of the latter include apparel discarded due to natural variations in the fibre or vegetable trimmings rejected during processing (or even in the kitchen) that are the result of overly strict specifications. While food loss statistics typically only take into account the share of crops and products intended for human consumption, it is important that all losses and waste are investigated for further useful applications.

Everyone loses out in the linear approach

The material losses that have been described along the value chain impact the economy in very direct ways, as they are associated with real costs for both producers and consumers. These financial effects will be sustained and possibly exacerbated farther out as our natural capital becomes eroded and declines in performance over time. Moreover, the entire economic system is starting to experience a whole new level of risk exposure. Nowhere does this play out more explicitly than in our agricultural supply chain, as the next section will explain.

Cost burdens
Recent spikes in input costs are an indication that the industry may be reaching a limit where demand starts to accelerate ahead of an ever more constrained supply. Most inputs to consumer goods, both agricultural and technical in nature, have seen high prices and unprecedented levels of volatility in recent years, creating pressure on companies' profitability. Businesses are feeling squeezed between rising and less predictable prices in resource markets on the one hand and stagnating demand in many mature consumer markets on the other.

Rising commodity prices. Commodity prices fell by roughly half in real terms over

13 Expert interviews, Ellen MacArthur circular economy team. Every litre of beer produced generates between 150 and 200 grams of brewers grains

14 FAO: Global Food Losses and Food Waste—Extent, causes and prevention, 2011

15 FAO: Global Food Losses and Food Waste—Extent, causes and prevention, 2011

16 WRAP, Valuing our clothes, 2012

the course of the 20th century. However, the start of the new millennium marked a turning point when the real prices of natural resources began to surge upwards. In a trend separate from the financial and economic crises, commodity prices in aggregate increased by nearly 150% from 2002 to 2010, erasing the last century's worth of real price declines. Price increases have hit not only metals, such as gold and copper, but also direct inputs for consumer goods. In 2011, for example, cotton prices in the US surged almost 40% in two months and remain at levels double the pre-2007 price of cotton.[17] Similarly, polyester prices increased from USD 1.3/kg in 2010 to USD 2.1/kg in 2011. Meanwhile, average clothing prices decreased from an average of USD 15.2 per garment in 2006 to USD 14.9 per garment in 2011.[18] The combination of higher input costs and lower retail prices is putting pressure on producers' margins and forcing them to seek ways to control rising input costs.

Increasing price volatility. At the same time, the last decade has seen higher price volatility for metals, food and non-food agricultural output than in any single decade in the 20th century.[19] High prices are one issue; their volatility is another. Higher volatility of resource prices can dampen economic growth by increasing uncertainty, and this may discourage businesses from investing. Volatility-induced uncertainty also increases the costs of hedging against resource-related risks; in his book 'Antifragile' Nassim Taleb states that the value at risk of black swan events like Hurricane Sandy cannot possibly be estimated—effectively rendering such future events uninsurable. Both prices and volatility are likely to remain high for a number of reasons. One is that populations are growing and urbanising, boosting demand. Resource extraction is also moving to harder-to-reach, less fertile and/or more politically unstable locations. Another factor is that the depletion of natural capital and the erosion of ecosystems services are continuing, with associated environmental costs on the rise but still largely treated as externalities.

Curbed economic growth. Together, high and volatile commodity prices dampen the growth of global businesses—and ultimately the economy at large. In February 2011, for instance, PepsiCo announced that they expected input costs for the fiscal year to rise by USD 1.4 – 1.6 billion, or between 8 and 9.5% of total input costs, due to commodity price increases.[20] PepsiCo also said they did not plan to fully offset these losses through price-hikes—highlighting another, parallel trend in which firms face a profit squeeze due to softer demand.[21] Similarly, H&M, the clothing company, suffered from a significant drop in profits in 2011 due to rising cotton prices that they did not pass on to customers through higher prices or lower quality.[22]

Loss of energy. Another financial and economic impact of note in the linear economy is the associated energy lost whenever materials are discarded somewhere in the value chain. The consumption of energy for biological inputs is significant. In the U.S., for example, food production and preparation represents 17% of all energy demand.[23] The incineration of discarded process waste or end-of-life products recoups only a small share of this energy.

Erosion of natural capital

Natural capital and ecosystem services

Natural capital is the potential value held in natural resources, which include mineral assets but also extend to biodiversity and ecosystems on which human activity and welfare depend. As defined by Robert Costanza at the University of Maryland in a seminal article published in Nature: 'Ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare.'[24] These services include for example carbon sequestration, crop pollination, or nutrient dispersal and cycling.

17 Indexmundi, average spot price for a pound of upland cotton

18 Price for 1.4/1.5 denier staple fibre

19 Annual price volatility calculated as the standard deviation of McKinsey commodity subindices divided by the average of the subindex over the time frame; Source: McKinsey Global Institute: Resource revolution: Meeting the world's energy, materials, food, and water needs, November 2011

20 'Pepsi faces steep input price inflation', Financial Times, 10 February 2011

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

22 'H&M hit by soaring cotton prices', Financial Times, March 2011

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

24 Robert Costanza et al, The value of the world's ecosystem services and natural capital, Nature Vol. 387, May 15, 1997

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Disposal's heavy toll. Regardless of the inherent lost value of discarded items, where these items end up is problematic in and of itself. From Greece to Indonesia and Mali to Kazakhstan, large shares of municipal solid waste end up in dumps or sub-standard landfills. If not conducted properly, dumping or landfilling creates both short- and long-term risks for human health and the environment in the form of harmful leachate, dust, odour, local traffic burden, and powerful greenhouse gas emissions. Any biodegradable material, from kitchen waste to paper and cardboard to wood and natural textiles, generates landfill gas when it decays under anaerobic conditions. Landfill gas consists of around 50% methane, which is a greenhouse gas over twenty times more powerful than CO_2. For each U.K. household, landfilled clothing results in 1.5 million tonnes of CO_2e[25] emissions per year—0.3% of total emissions.[26] Even sanitary landfills can be problematic as they require substantial space close to centres of consumption where land comes at a premium, and they are usually difficult to site due to community concerns, so all but a handful of areas are running out of space. Beijing will have no more landfill space in 4 years' time, Johannesburg in around 12 years, and the entire U.K. will run out of landfill capacity by 2018 if it continues its current disposal practices.

Moreover, much consumer goods waste never enters a waste collection system, instead ending up as litter, giving rise to a familiar list of problems. Unmanaged waste can lead to the injury and death of local wildlife and end up offshore where it can accumulate on beaches, in open waters (cf. the Pacific Garbage Patch) in fish, birds, and other animals—and ultimately in our own food chain. Because it is unsightly, litter can also impact the attractiveness of a location as a tourist destination or for business.

The erosion of 'ecosystem services'. The loss of those benefits derived from ecosystems that support and enhance human wellbeing also deserves our full attention.[27] 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, the global economy is now reducing the Earth's natural capital, and is unable to generate the necessary surplus to rebuild the deficit.[28,29] Take land degradation.'Today's agriculture does not allow the soil to enrich itself, but depends on chemical fertilisers that don't replace the wide variety of nutrients plants and humans need' says Dr Tim Lobstein, the U.K.'s Food Commission director.[30] Land degradation costs an estimated USD 40 billion[31] annually worldwide, without taking into account the costs of increased fertiliser use, loss of biodiversity, and loss of unique landscapes.

Global scope of risk exposure
Concern over the economic costs of the linear economy has recently been joined by worries over the uncertain effects of climate change and geopolitical interconnectedness.

Recent research has highlighted nine interlinked 'planetary boundaries'—thresholds that, if crossed, represent a significant risk to the resilience of the world's social and economic structures, especially for the most vulnerable communities, and could potentially destabilise the wider ecosystem.[32] Examples of these thresholds are greenhouse gas emissions that induce climate change, rates of biodiversity loss, and interference with global phosphorus and nitrogen cycles. A recent study by the Economics of Climate Adaptation Working Group that focused on the economic impact of current climate patterns and potential climate change scenarios in 2030 found that some regions were at risk of losing 1 to 12% of their GDP annually as a result of existing climate patterns.

Geopolitical risk. The destabilising effects of such losses also translate into greater political risks. Recent history shows the impact political events can have on commodity supply. Rising grain prices are considered a factor that contributed to the 'Arab Spring' unrest (grain prices rose by 37% in Egypt in 2007-2008).[33,34] Some commodities are particularly vulnerable: nearly half the new projects to develop copper reserves are in countries with high political risk.[35] Approximately 80% of all available arable land on earth lies in areas afflicted by political or infrastructural issues. Some 37% of the world's proven oil reserves

25 CO_2e stands for carbon dioxide equivalent. This is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tons of methane is equivalent to emissions of 21 million metric tons of carbon dioxide (http://stats.oecd.org/glossary/detail.asp?ID=285).

26 U.K. Department of Energy and Climate Change statistics, 2012

27 One compelling and often overlooked example of such ecosystem services is healthcare: the pharmaceutical industry makes heavy use of biodiversity. Of all the anti-cancer drugs available today, 42% are natural and 34% are semi-natural. Source: Newman DJ, Cragg GM. Natural products as sources of new drugs over the last 25 years. J Nat Prod. 2007

28 Ruth DeFries et al, Millennium Ecosystem Assessment, Current State & Trends Assessment, 2005

29 Will Steffen et al, The Anthropocene: From Global Change to Planetary Stewardship, 2011

30 www.guardian.co.uk/uk/2006/feb/02/foodanddrink

31 Klaus Kellner et al, Terminal Evaluation of the UNEP/FAO/GEF Project 'Land Degradation Assessment in Drylands (LADA)', May 2011

32 Johan Rockström et al, Planetary Boundaries: Exploring the Safe Operating Space for Humanity, Ecology and Society 2009

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

34 The Observer, 16 July 2011

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

and 19% of proven gas reserves are in countries with a high level of political risk. Political motives also drive cartels, subsidies, and trade barriers, all of which can trigger or worsen resource scarcity and push up prices and volatility levels.

Greater interconnectedness of resources is a related issue. Commodity prices now show significant correlation with oil prices—and this holds true not only for metals and mining products, but for food categories such as maize, wheat, and rice as well as beef. These links increase the risk that shortages and price changes in one resource can rapidly spread to others.

The swift integration of financial markets and the increasing ease of transporting resources globally also mean that regional price shocks can quickly become global. As the World Bank's 'Turn Down the Heat' report notes, specialisation in production systems is continuing its unstoppable evolution and has gone international: our dependence on infrastructure to deliver produced goods is therefore growing—and with it, our economic exposure to events across the world. Natural catastrophes with ripple effects are numerous in recent history: Hurricane Sandy (with costs estimated at USD 100 billion) on the U.S. East Coast just last October, and Typhoon Bopha in the Philippines in December 2012 (which according to early estimates caused a GDP loss of 0.3%).[36]

This trend is likely to continue and become more acute as emerging markets integrate more thoroughly into global value chains and financial systems. Many up-and-coming economic centres in Asia, such as Kolkata (Calcutta), Ho Chi Minh City, or Ningbo, are situated on the coast and are not only accumulating assets at breakneck pace but also house growing numbers of immigrants in low-lying, flood-prone areas.[37] Because of their role in regional and global markets, severe damage to any of these cities by a storm affects nearby and far-away regions alike. The cost associated with such events is no longer simply that of local repairs and has considerable social consequences. Large-scale business interruption represents a very real setback in regional and potentially global economic growth. 2011's record flooding in and around Bangkok disabled several of its industrial areas, with knock-on effects in the global automotive and computer industries: a quarter of the world's computer hard disks are made in Thailand.[38]

The end of agriculture as we know it

The agricultural supply chain is the most important supply chain for the consumer goods industry. Agricultural demand, which has seen strong growth in the past, is expected to keep expanding as both populations and incomes rise. By 2030, demand for the top four agricultural products—rice, wheat, soy and maize—is expected to rise 40 - 50% above 2010 levels.[39,40] It is therefore worth contemplating how the material losses, financial effects and especially systems implications play out in this sector.

Historically, the application of technology and products, particularly the combination of irrigation, mineral fertilisers, and pesticides used in the 'Green Revolution', have generated impressive results, allowing supply to keep pace with the increase in demand (Figure 3). There are, however, signs that the agricultural system as we know it is reaching its limits. The growth of grain yields has slowed to below population growth rates in most regions—a sign that natural limits have been reached. Overall, worldwide cereal productivity growth has slowed over time from 2.7% in the 1970s to 1.3% in the 2000s.[41] As U.S. investor Jeremy Grantham remarked in his July 2012 newsletter:[42] 'Quite probably, the most efficient grain producers are approaching a 'glass ceiling' where further increases in productivity per acre approach zero at the grain species' limit (just as race horses do not run materially faster now than in the 1920s).' Several factors are expected to further exacerbate the stagnation of yield improvements, including a decrease in public spending on agricultural R&D, increased soil degradation, greater water scarcity, and climate change.

36 The Economist Intelligence Unit

37 Too big to flood, The Guardian, 17 December 2012

38 Too big to flood, The Guardian, 17 December 2012

39 USDA, FAO, expert interviews
This includes demand from energy and feed applications

40 Food and Agriculture Organization of the United Nations Statistical Division (FAOSTAT)

41 GMO Quarterly Newsletter, 'Welcome to Dystopia' July 2012, available at www.gmo.com

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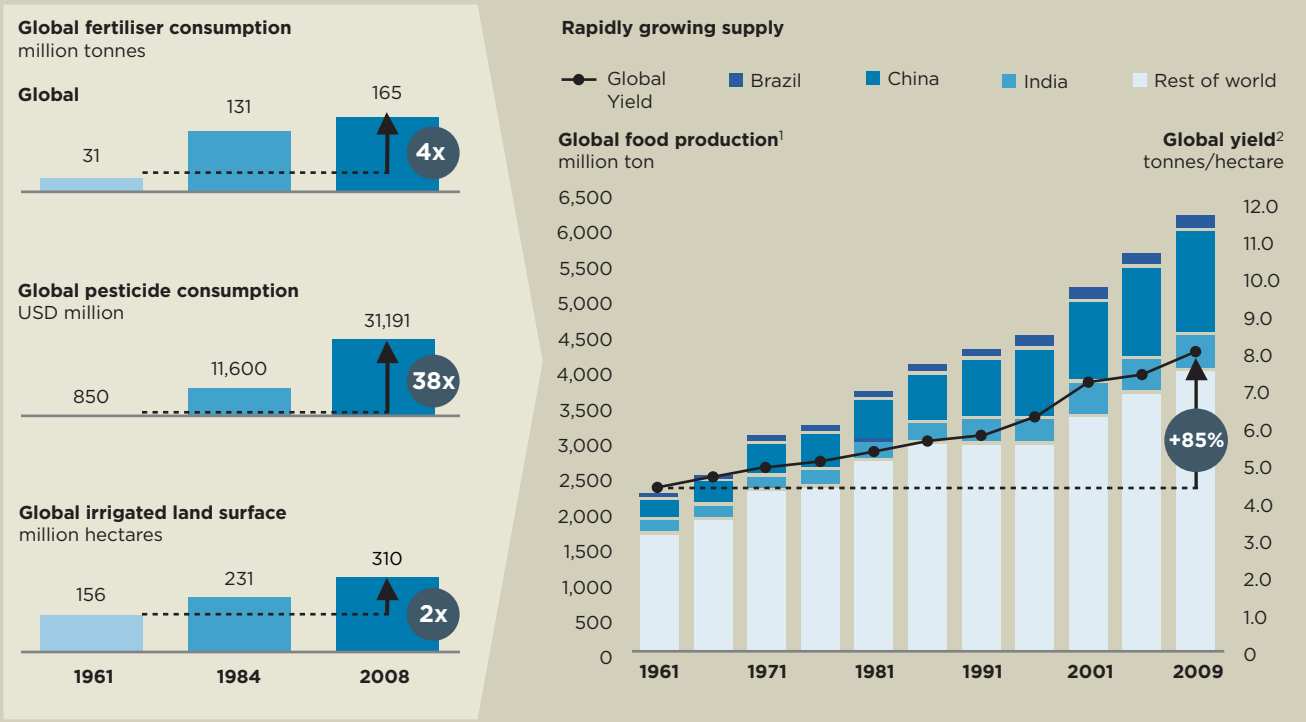
FIGURE 3 **Application of technology and products have generated impressive results over the last 50 years**



1 Includes cereals, citrus fruit, course grain, primary fibre crops, fruit, primary oil crops, pulses, roots and tubers, tree nuts, vegetables
2 Weighted average of the above agricultural products

SOURCE: FAO; Zhang, Jiang and Ou, 2011

Since the invention of the Haber-Bosch process in 1909, which allowed production of nitrogen fertiliser on an industrial scale, cheap fossil fuels have enabled mineral fertilisers to unlock agricultural yield improvement in many regions. As farming expands to feed the world's increasing population and its changing diets, rising demand is likely to cause fertiliser prices to rise and become more volatile. Demand for phosphorus, for example, is projected to grow by 3% a year through to 2020.[43] Fertiliser prices have already entered a new phase of volatility since around 2005, with price fly-ups of a magnitude not seen since the 1970s, when the Green Revolution and use of fertiliser dramatically increased world food production.

Soil degradation is estimated to extend to some 25 - 35% of the 1.5 billion hectares of land under cultivation,[44] meaning that it is less fertile, less able to retain water, less able to fend off pests, and more prone to erosion. Loss of soil carbon is problematic given the role of this carbon in several developing and maintaining factors that are critical to plant growth, such as soil texture, water retention and nutrient delivery to the roots of plants. In Europe, around 45% of soils have low or very low organic matter content, 45% have medium content.[45]

Another very important form of degradation is nutrient depletion. There are indications that intensive agriculture—scientists and agricultural engineers have been very successful at multiplying the amount of biomass we can grow on a single hectare—takes out more nutrients from the soil than are returned, leading to both macro- and micronutrient deficiencies.

Macronutrients are those key nutrients responsible for healthy plant growth that are required in fairly large amounts. It takes

43 McKinsey Phosphorus Demand Model, Cordell, D. phosphorus research studies, 2009; Ellen MacArthur circular economy team

44 International Soil Reference and Information Centre, Oregon State University, Resource Conversation and Food Security

45 Low or very low organic matter content means 0 - 2% organic carbon, medium content means 2 - 6% organic carbon

centuries to build up the nitrogen stocks in the soil through natural processes.[46] The global consumption of NPK fertilisers (Nitrogen (N), Phosphorus (P), Potassium (K)) increased by 435% from 1961 to 2009 (from 31 million tons to 167 million tons)[47], but many soils now suffer from a negative nutrient balance, where nutrient removal is greater than the input.[48] Negative nutrient balance is not just an issue in developing countries like India and Africa: much of the U.S. Corn Belt has a negative P balance, and the entire western half of the country has a highly negative K balance.[49]

Intensive agricultural practices have also resulted in micronutrient depletion in several parts of the world. *Micronutrients* are not less critical to plant health but are required in relatively small amounts. Depletion is not just the result of a negative removal-vs.-input balance but also of several other factors such as high N, P and K application, low manure applications and excessive irrigation. Zinc deficiency appears to be the most widespread and frequent micronutrient deficiency problem in crop and pasture plants worldwide, resulting in severe losses in yield and nutritional quality, especially in cereal production. It is estimated that nearly half the soils on which cereals are grown have levels of available zinc so low as to cause zinc deficiency.[50] A typical example of nutrient-deficient food is a study in Haryana, India, where low levels of zinc in buffalo milk were directly linked to low zinc levels in local soils, and in fodder produced on these soils.[51]

According to a U.S. Department of Agriculture study in 2004 that followed 14 key nutrients in a range of vegetable crops, the nutrient content of 12 had declined from 1950 to 1999.[52] While not necessarily an immediate result of nutrient imbalances in the soil, this is linked to the same industrial approach to agriculture that leads to soil nutrient deficits, as these deficiencies are usually the result of changes in cultivated varieties, where there may be trade-offs between higher yield, size and appearance at the expense of lower nutrient content.

Mineral fertilisers also generate negative externalities beyond the agricultural production system, as agricultural fertiliser run-offs are the main contributor to reduced oxygen levels in inland waterways and coastal areas, creating 'dead zones' where fish cannot survive. The number of these has approximately doubled each decade since the 1960s, now covering part of the ocean as large as the U.K.[53]

Furthermore, a recent study has linked industrial farming in the U.S. Midwest to increased insect pest occurrence and insecticide usage.[54] Conversion to intensive monocultures increases pest populations as natural habitats for pest predators are removed and dense cover crops (as used in crop rotation) are no longer available to suppress weeds. This intensifies the use of pesticides and herbicides, induces the loss of biodiversity, and can give rise to adverse human health effects.

The circular vision

Upcoming growth in demand could strain the linear economy to breaking point. Taken together, the dynamics described in this chapter present a major challenge for the current 'take-make-dispose' system. While this system will respond to price signals, these signals are incomplete and distorted. USD 1.1 trillion is spent annually on resource subsidies (agriculture, fishing, energy and water), for example.[55] We therefore believe that the market will not overcome the lock-in effect of existing production economics, regulations and mindsets in a business-as-usual scenario, and will not address the large and continued imbalances described here quickly and extensively enough to be able to keep meeting future demand. If this is the case, the resulting upward price shifts could, if not stall, then at least severely hamper further growth in the decades to come.

In this report, we investigate how 'circular' business models could provide new opportunities for resilient growth despite a challenging global outlook. With a focus on optimising production/consumption systems comprehensively rather than maximising the performance of individual elements, the term 'circular economy' denotes an industrial economy that is restorative by intention and design. In addition to meeting current demand/consumption needs, a circular economy also actively invests in improving resource systems and increasing

46 Allen, R.C. 2008. The nitrogen hypothesis and the English agricultural revolution: A biological analysis. The Journal of Economic History, 68: 182-210

47 Food and Agriculture Organization of the United Nations Statistical Division (FAOSTAT)

48 Globally, soil nutrient deficits were estimated at an average rate (kg ha-1 yr-1) of 18.7 N, 5.1 P, and 38.8 K, accounting for 59%, 85%, and 90% of harvested area in the year 2000, respectively. The annual total nutrient deficit was 5.5 million tonnes N, 2.3 million tonnes P, and million 12.2 tonnes K, coupled with a total potential global production loss of 1,136 tonnes yr-1. Source: Z. X. Tan, R. Lal & K. D. Weibe (2005): Global Soil Nutrient Depletion and Yield Reduction, Journal of Sustainable Agriculture, 26:1, 123-146

49 IPNI. 2012. A Nutrient Use Information System (NuGIS) for the U.S. Norcross, GA. January 12, 2012. Available online www.ipni.net/nugis

50 B. J. Alloway: Zinc in Soils and Crop Nutrition, published by IZA and IFA Brussels, Belgium and Paris, France, 2008

51 S. Yadav et al: Soil-plant-animal relationship of zinc in milk buffaloes of Jind district in Haryana, 2000, Indian Journal of Animal Sciences 70: 965-967

52 Examples include 79% less iron in cucumbers, 63% less vitamin B2 in lettuce, and 55% less calcium in tomatoes. Source: DR Davis et al, Changes in USDA food composition data for 43 garden crops, 1950 to 1999, Journal of the American College of Nutrition, December 2004; USDA

53 Diaz & Rosenberg, 2008; http://sailorsforthesea.org/Sailing-and-The-Environment/Ocean-Watch/Ocean-Watch-Essays/Ocean-Dead-Zones.aspx

54 Timothy Meehan et al, Agricultural landscape simplification and insecticide use in the Midwestern United States, PNAS June 2011

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

1. The limits of linear consumption
Continued

their resilience to ensure their continuing availability in the future. In short, it replaces a throughput- and efficiency-driven view that ultimately degrades capital with one where capital rebuilding and maintenance offers an upward spiral or virtuous cycle, and a continuous flow of materials and products. In a circular economy, agricultural practices aim at optimising yields while also improving the quality of soil, water, and air. It views the long-term health of our agricultural systems as our best chance for long-term performance.

Our preliminary research shows that moving to such a model could lead to significant economic benefits. It could help mitigate the aspects of the current system that put pressure on resource supply, raise commodity prices, and increase price volatility. It could also rebuild valuable natural asset value and enable the resilient provision of food, feed and fibre.

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

From linear to circular
Accelerating a proven concept

2

Discussing how the principles of the circular economy apply to consumer goods—within both the biological and the technical spheres.



2. From linear to circular
Accelerating a proven concept

The linear 'take-make-dispose' economic model relies on large quantities of easily accessible resources and energy. Much of our existing efforts to decouple the global economy from resource constraints focus on driving 'linear' efficiencies—i.e., a reduction of resources and fossil energy consumed per unit of manufacturing output. Proponents of the circular economy argue that focussing on efficiency alone will not alter the finite nature of resource stocks, and—at best—simply delays the inevitable. A change of the entire operating system is necessary.

The concept of the circular economy

The circular economy refers to an industrial economy that is *restorative* by intention. It aims to enable effective flows of materials, energy, labour and information so that natural and social capital can be rebuilt. It seeks to reduce energy use per unit of output and accelerate the shift to renewable energy by design, treating everything in the economy as a valuable resource. The idea goes beyond the requirements of the production and consumption of goods and services. The concept of the circular economy is grounded in the study of real-world, non-linear, feedback-rich systems, particularly living systems. A major outcome of taking insights from living systems and applying them to the economy is the notion of optimising systems rather than components. Context is everything, so the rebuilding of capital stocks to provide productive and long-lasting flows is an integral part of this 'design to fit' approach. The circular economy requires careful management of material flows, which are of two types. These are characterised by McDonough and Braungart in *Cradle to Cradle: Remaking the Way We Make Things as biological nutrients*—materials designed to re-enter the biosphere safely and rebuild natural capital, and *technical nutrients,* designed to circulate at high quality without entering the biosphere.[56]

As a result, the circular economy draws a sharp distinction between the consumption and use of materials. Consumption is the inevitable fate of materials like food and drink that are irreversibly altered during their useful life, and can no longer be put to the same use afterwards. In a linear system, this irreversibility of consumption is also the fate of the many technical materials—tied up in one-way packaging, fast fashion, or semi-durables. A circular economy, however, advocates the increasing use of a 'functional service' model for technical materials, in which manufacturers or retailers retain ownership of their products (or have an effective take-back arrangement) and, where possible, act as service providers, selling the use or performance of products, not their consumption. This shift has direct implications for the development of business models that create value in novel ways. Innovator and industrial analyst 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'.[57]

Based on natural principles

The circular economy takes its insights from living systems as these have proved adaptable and resilient, and model the 'waste is food' relationship very well. They also bring insights around the cascading of materials as a way of recognising and capturing value as entropy (disorder) increases.

Design out waste. Waste does not exist when the biological and technical components of a product are designed by intention to fit within a biological or technical materials *cycle* designed for remarketing, remanufacture, disassembly or repurposing. The biological materials are non-toxic and can easily be returned to the soil by composting or anaerobic digestion, and may also yield higher-value substances before decomposing. Technical materials—polymers, alloys, and other man-made materials—are designed to be recovered, refreshed and upgraded, minimising the energy input required and maximising the retention of value (in terms of both economics and resources). This is a vital difference versus recycling within a linear economy, which takes products never designed for regeneration by intention and often results in a rapid degradation of value.

56 William McDonough and Michael Braungart, Cradle to Cradle: Remaking the Way We Make Things, New York: North Point Press, 2002.

57 Unless explicitly stated otherwise, all quotations in this document are from interviews conducted in the period from October 2012 through January 2013 (a list of experts consulted for the analysis and reporting is given in the appendix).

Efficiency vs. effectiveness—a key distinction

Eco-efficiency begins with the assumption of a one-way, linear flow of materials through industrial systems: raw materials are extracted from the environment, transformed into products, and eventually disposed of. In this system, eco-efficient techniques seek only to minimise the volume, velocity, and toxicity of the material flow system, but are incapable of altering its linear progression. Some materials are recycled, but often as an end-of-pipe solution, since these materials are not designed to be recycled. Instead of enabling another 'cycle', this process actually sees products, components and materials lose value. This downgrading of material quality limits usability and maintains a linear, cradle-to-grave dynamic of materials within the economy.

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

Build resilience through diversity. Modularity, versatility and adaptivity are prized features that need to be prioritised in an uncertain and fast-evolving world. Production systems should be flexible—able to use many different inputs. Diverse systems with many nodes, connections and scales are more resilient in the face of external shocks than systems built simply for efficiency—throughput maximisation—as this results in brittleness. Since efficiency can introduce additional risk, there is a business case for allocating resources to building resilience, rather than using them as a reserve fund.

Shift to renewable energy sources. Systems should ultimately aim to run on renewable energy—enabled by the reduced threshold energy levels required by a restorative, circular economy. The agricultural production system runs on current solar income but significant amounts of fossil fuels are used in fertilisers, farm machinery, processing and through the supply chain. More integrated food and farming systems would reduce the need for fossil-fuel based inputs and capture more of the energy value of by-products and manures. They would also increase the demand for human labour—which Walter Stahel has argued should be an integral part of this evolution: 'Shifting taxation from labour to energy and material consumption would fast-track adoption of more circular business models; it would also make sure that we are putting the efficiency pressure on the true bottleneck of our resource-consuming society/economy—there is no shortage of labour and (renewable) energy in the long term.'

Think in systems. The ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts, is crucial. Elements are considered in relation to their environmental and social contexts. While a machine is also a system, it is clearly narrowly bounded and assumed to be deterministic. Systems thinking usually refers to the overwhelming majority of real-world systems: these are non-linear, feedback-rich, and interdependent. In such systems, imprecise starting conditions combined with feedback lead to often surprising consequences, and to outcomes that are frequently not proportional to the

2. From linear to circular
Continued

input (runaway or 'undamped' feedback). Such systems cannot be managed in the conventional, 'linear' sense, requiring instead more flexibility and more frequent adaptation to changing circumstances. Systems thinking emphasises stocks and flows. The maintenance or replenishment of stock is inherent in feedback-rich systems, which are assumed to have some longevity, and has the potential to encompass regeneration and even evolution in living systems. In a business context, their modular and adaptive properties mean more leeway for innovation and the development of diversified value chains, as well as less dependence on purely short-term strategies.

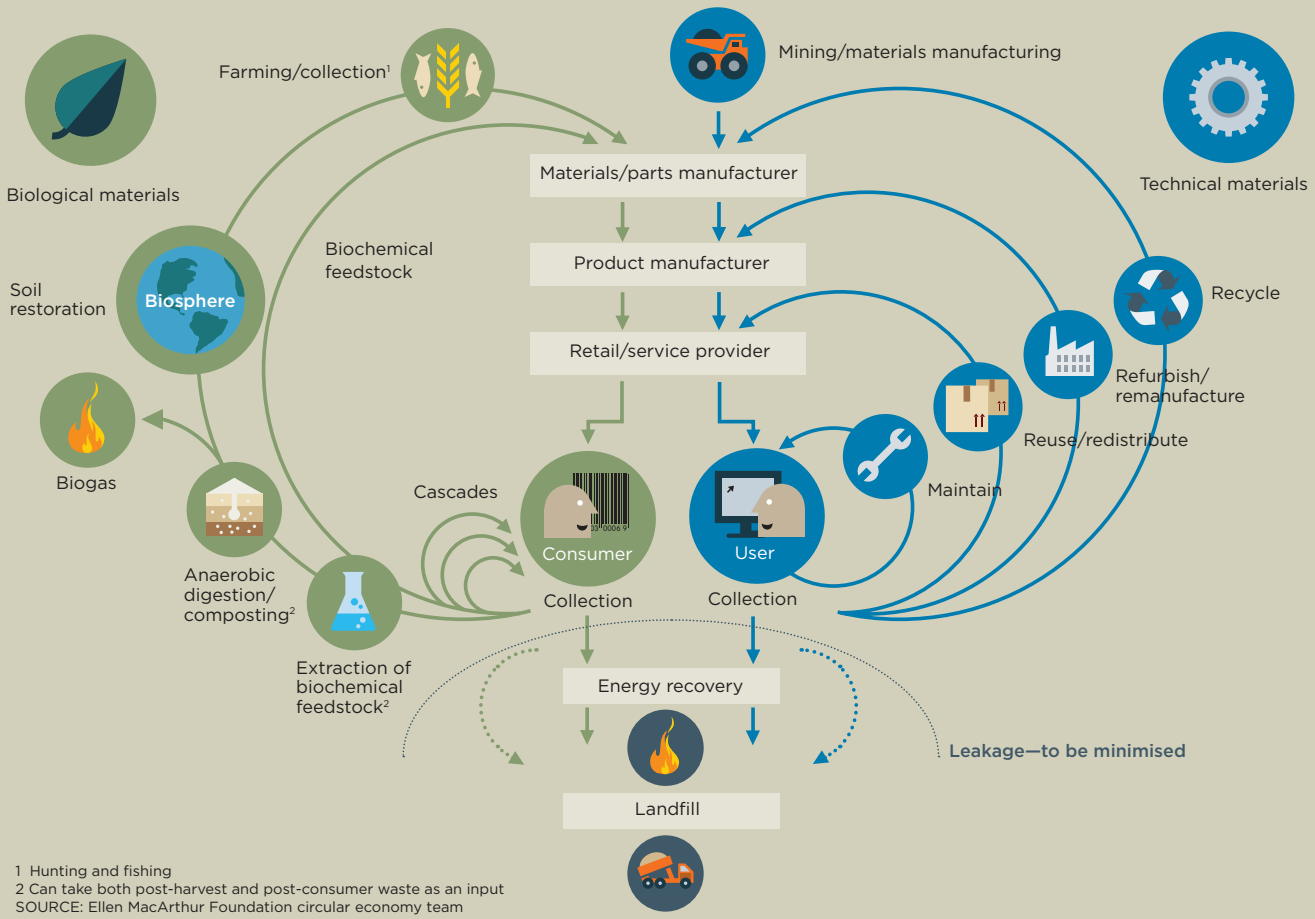
Understanding flows in complex systems also tells us something more about the trade-off between efficiency and resilience. Systems that are increasingly efficient have fewer nodes, fewer connections, and greater throughput but also become increasingly brittle or—to use Nassim Taleb's term—'fragile'. This makes them vulnerable to the effects of shocks like price volatility or interruption of supply. Systems with many nodes and connections are more resilient, but can become sclerotic—slow to change (at the extreme), and thus ineffective. Effectiveness is the sweet spot where resilience and efficiency interplay: efficiency (doing things right) is welcome, but in the service of effectiveness (doing the right thing), with the prime objective of ensuring the business fits the economy. This is another way of seeing the systems optimisation question discussed earlier. Because more of the flows of materials, goods, and services are valorised in a circular economy and because risk is reduced, the firm is compensated for the reduced upside of efficiency with lower costs, additional cash flows and—in many cases—fewer regulatory concerns (as wastes are eliminated, or are now benign flows).

Think in cascades. For biological materials, the essence of value creation lies in the opportunity to extract additional value from products and materials by cascading them through other applications. In biological decomposition, be it natural or in controlled fermentation processes, material is broken down in stages by microorganisms like bacteria and fungi that extract energy and nutrients from the carbohydrates, fats, and proteins found in the material. For instance, going from tree to furnace forgoes the value that could be harnessed via staged decomposition through successive uses as timber and timber products before decay and eventual incineration.

The complete biological entity should be considered. Mycelium packaging, an innovation based on the bonding properties of mushroom 'roots', uses the entire 'living polymer'—as well as the organic waste system on which it grows. A holistic, cascade-based relationship with coffee would consider the entire fruit (the cherry) and the whole coffee-growing protocol. The entire shrub in its context also needs integrating: as a shade-loving plant, it may well be positioned adjacent to other trees. In addition, coffee production generates 12 million tonnes of agricultural waste per year. This waste could be used to replace hardwoods traditionally used as growth media to farm high-value tropical mushrooms, a market with double-digit growth (currently USD 17 billion globally). Coffee waste is in fact a superior medium, as it shortens the production period. The residue (after being used as a growth medium) can be reused as livestock feed, as it contains valuable enzymes, and can be returned to the soil in the form of animal manure at the end of the cascade.[58]

58 http://theblueeconomy.org/blue/Case_3_files/Case%203%20Coffee.pdf

FIGURE 4 **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

Figure 4 illustrates how biological and technical materials (and the products/components based on them) cycle through the economic system, each with their own set of characteristics. Unlike biological materials, technical materials are not cascaded to other applications but the functionality, integrity and the value of embedded energy are maintained through remarketing, reuse, disassembly, refurbishment and remanufacture. The second law of thermodynamics prevents endless unaltered cycles—everything decays. How this circular system would work will be elaborated on later in this chapter.

2. From linear to circular
Continued

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 developed and refined by the following schools of thought.

Regenerative Design. In the 1970s, an American professor named John T. Lyle launched a challenge for graduate students. Lyle asked students to forge ideas for a society in which 'daily activities were based on the value of living within the limits of available renewable resources without environmental degradation', according to a California research centre that is now named after Lyle.[59] 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). See for example *Regenerative Design for Sustainable Development* (Wiley, 1994).[60]

Performance Economy. Walter Stahel, architect and industrial analyst, sketched the vision of an economy in loops (or circular economy) and its impact on job creation, economic competitiveness, resource savings, and waste prevention in his 1976 research report to the European Commission *The Potential for Substituting Manpower for Energy,* co-authored with Genevieve Reday.[61,62] Stahel's Product-Life Institute, considered one of the first pragmatic and credible sustainability think tanks, pursues four main goals: product-life extension, long-life goods, reconditioning activities, and waste prevention. It also insists on the importance of selling services rather than products, an idea referred to as the 'functional service economy', now more widely subsumed into the notion of 'performance economy'. Stahel argues that the circular economy should be considered a framework, and its supporters see it as a coherent model that forms a valuable part of a response to the end of the era of low-cost oil and materials.

Cradle to Cradle. In the 1990s, German chemist and visionary Michael Braungart went on to develop, together with American architect Bill McDonough, the Cradle to Cradle™ concept and certification process. This design philosophy considers all material involved in industrial and commercial processes to be nutrients, of which there are two main categories: technical and biological. The Cradle to Cradle framework focuses on design for effectiveness in terms of product flows with positive impact, which fundamentally differentiates it from the traditional design focus on reducing negative impacts.

Cradle to Cradle design sees the safe and productive processes of nature's 'biological metabolism' as a model for developing a 'technical metabolism' flow of industrial materials. The model puts particular emphasis on precisely defining the molecular composition of materials: 'knowing what you have, which is the basis of every quality-based materials recycling system'. In some cases, durability is not the optimal strategy—some (parts of) consumer goods end up very dispersed because of consumption patterns or are extremely hard to retrieve for different reasons, for example because of severe soiling. In such instances, it is preferable to design the products such that material purity is maintained throughout, rendering it easier to extract their regenerative powers and return them to the land. 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'.

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

60 Regenerative Design for Sustainable Development (The Wiley Series in Sustainable Design) by John Tillman Lyle, John Wiley & Sons, 1994.

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

62 http://www.product-life.org/en/major-publications/performance-economy

63 www.biomimicryinstitute.org

Industrial Ecology. Industrial ecology is the study of material and energy flows through industrial systems. Focusing on connections between operators within the 'industrial ecosystem', this approach aims at creating closed-loop processes in which waste serves as an input, 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, while 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.

Blue Economy. Initiated by former Ecover CEO and Belgian businessman Gunter Pauli, the Blue Economy is an open-source movement bringing together concrete case studies, initially compiled in an eponymous report handed over to the Club of Rome. As the official manifesto states, 'using the resources available in cascading systems, (...) the waste of one product becomes the input to create a new cash flow'. Based on 21 founding principles, the Blue Economy insists on solutions being determined by their local environment and physical/ecological characteristics, putting the emphasis on gravity as the primary source of energy. The report, which doubles up as the movement's manifesto, describes '100 innovations that can create 100 million jobs within the next 10 years', and provides many examples of winning South-South collaborative projects—another original feature of this approach intent on promoting its hands-on focus.

Biomimicry. Janine Benyus, author of *Biomimicry: Innovation Inspired* by Nature, defines her approach as 'a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems'. Studying a leaf to invent a better solar cell is an example. She thinks of it as 'innovation inspired by nature'.[63] Biomimicry relies on three key principles:

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

Permaculture. Australian ecologists Bill Mollison and David Holmgren coined the term 'permaculture' in the late 1970s, defining it as 'the conscious design and maintenance of agriculturally productive ecosystems, which have the diversity, stability and resilience of natural ecosystems'. Considerable interest in the concept exists around the globe, propelled by thinkers and practitioners like Masanobu Fukuoka in Japan and Sepp Holzer in Austria. Permaculture draws elements from both traditional sustainable agriculture and modern innovations and principles. Permaculture systems improve yields and diets while reducing water consumption, improving soil quality and restoring biodiversity. Permaculture integrates elements from agroforestry (forest farming, alley cropping, windbreaks), conservation agriculture (fertiliser trees, no till and uncompacted soils, permanent soil cover), organic agriculture (organic inputs and on-site nutrient recycling), and traditional agriculture (rainwater harvesting and water infiltration, including key-line design and tied contour bunds). Further aspects it covers are sustainable livestock management (integrated crop-livestock systems) for subsistence smallholders and commercial operations, and agro-ecology (the optimal selection of system elements originating in different times and places). It deploys methods that are compatible with the sustained intensification of production.

2. From linear to circular
Continued

Terminology

• Fast-moving consumer goods (or 'consumer packaged goods')
Fast-moving consumer goods are characterised by high throughput volumes and frequent purchases; they represent a large physical volume and come at relatively low prices. Most fast-moving consumer goods have a short to very short lifespan. Some product categories are literally consumed, others are deployed for only a relatively short time or used just a few times. Fast-moving consumer goods include food and beverages, apparel, beauty products, and others. In the remainder of this report when we refer to 'consumer goods' we mean 'fast-moving consumer goods'—and their packaging.

• Reuse of goods
The renewed use of a product 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.

• Cascaded use of components and materials
Putting materials and components to different uses after the end of their lives across different value streams and extracting their stored energy and material 'coherence'. Along the cascade, their material order declines (in other words, entropy increases).

• Materials recycling
– Functional recycling. The process of recovering materials for the original purpose or for other purposes, excluding energy recovery.

– Downcycling. The process of converting materials into new materials of lesser quality, economic value, and/or reduced functionality.

– Upcycling. The process of converting materials into new materials of higher quality, economic value, and/or increased functionality.

• Biochemicals extraction
Applying biomass conversion processes and equipment to produce low-volume but high-value chemical products. In a 'biorefinery' these processes are combined to produce more than one product, and fine chemicals extraction can be combined with the extraction of bulk chemicals as platform molecules or for fuel production.

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

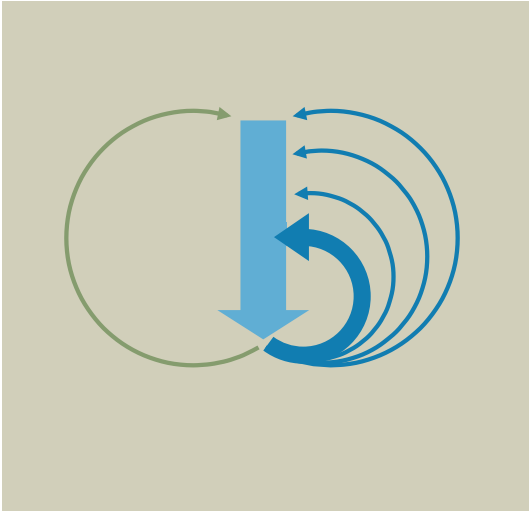
• Composting
A biological process in the presence of oxygen during which microorganisms (e.g., bacteria and fungi), insects, snails, and earthworms break down organic materials (such as leaves, grass clippings, garden debris, and certain food wastes) into a soil-like material called compost. Composting is a form of recycling, a natural way of returning biological nutrients to the soil. In-vessel composting (IVC) is an industrial form of rapid composting under controlled conditions.

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

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

Sources of value creation

The principles of the circular economy offer not just a description of how it should work as a whole, but also a guide to where the profit pools are. The economics and relative attractiveness of different circular models (reuse versus remanufacturing versus recycling, for example) vary significantly for different products and markets, all of which we spell out in the next chapter. Abstracting from the differences, we have identified four models (plus 'regeneration' as the heart of the circular economy), as patterns for creating more value from the materials used in consumer goods. The overarching fundamentals remain the same in all cases.



• Retain resource value by converting today's 'waste' streams into by-products—creating new effective flows within or across value chains.

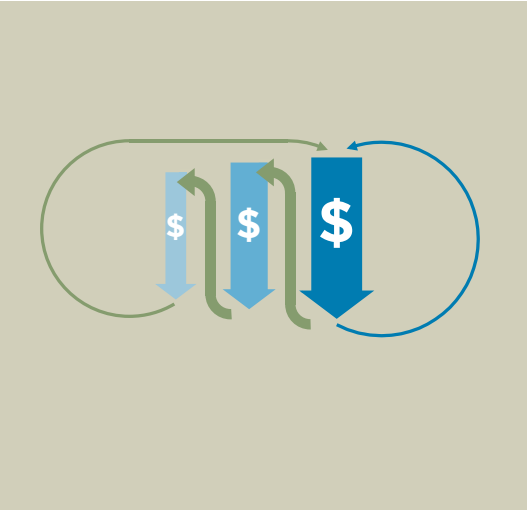
• Retain the overall effectiveness of the system—do not optimise individual parts of a process or design while neglecting the impact of such changes on the system as a whole. This requires knowledge of the system in its geographical context as well as its performance and evolution over time.

Power of the inner circle

The closer the system gets to direct reuse, i.e., the perpetuation of its original purpose, the larger the cost savings should be in terms of material, labour, energy, capital and the associated externalities, such as greenhouse gas emissions, water, or toxic substances. This opportunity applies mainly to the elements of fast-moving consumer goods that still exist 'beyond the end user', such as packaging or goods that can be directly reused such as apparel. Given the inefficiencies along the linear supply chain, tighter circles will also benefit from a comparatively higher virgin material substitution effect. Consumer goods in general have a relatively low unit value, very high throughput, and account for a large proportion of household waste. As a result, greater direct reuse—by circulating the same packaging multiple times, for example—can substantially reduce the amount of virgin material needed, and its embedded and associated costs. Whenever the costs to the economy of collecting and reprocessing the product, component or material, are lower than the linear alternative (including the avoidance of end-of-life treatment costs), circular systems can be economical. This arbitrage opportunity, revealed by contrasting a linear with a circular setup, is at the core of the circular economy's relative economic value creation potential.
For consumer goods and their packaging, opportunities lie in building efficient (re) distribution systems that result in reuse at scale: collecting and washing bottles to refill them with beverages, or reusing clothing instead of performing single-sale transactions. Higher resource prices and fully reflecting externalities such as avoided landfill can make this arbitrage more attractive. This is especially important as such systems get started, given that they typically require high density levels and volumes to make collection efficient and worthwhile.

2. From linear to circular
Continued





Power of circling longer
A second way to create value stems from keeping products, components, and materials in use longer within the circular economy. This can be achieved by either designing products and systems that enable more consecutive cycles or by spending more time within a single cycle. Such shifts primarily require greater durability. For garments this could mean yarns, fabrics, and finishes that are more resistant to wear and tear, designs that can be easily repaired, or styles that can be updated while in use. Higher resource prices and increased commodity price volatility will render this approach to value creation even more attractive.

True consumables like food will by definition cycle only once. Many will never even complete that one cycle: they may be discarded, or diverted from their intended use. It is important to review excessively stringent product specifications, improve stock management, and make better household choices to help ensure that such products are put to good use in their once-only cycle.

For true consumables and other consumer goods alike, a further necessity is applying technology and building awareness to improve recovery rates from current recycling systems—and by doing so, retain a higher proportion of the material within the cycle.

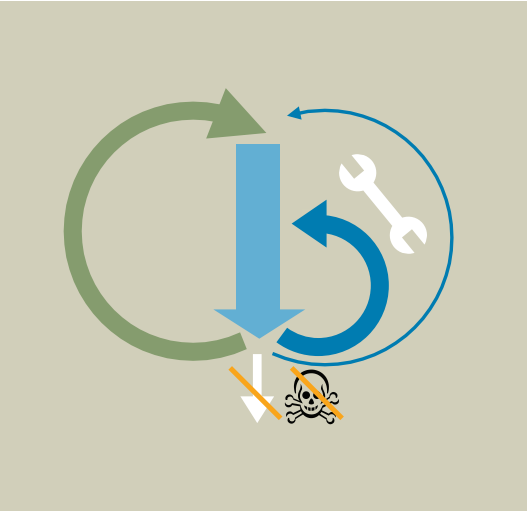
Power of cascaded use across industries and inbound material/product substitution
While the previous value creation opportunities refer to reusing products and materials, there is also an arbitrage opportunity in using discarded materials from one value chain as by-products, replacing virgin material inflow in another. The arbitrage value creation potential in these cascades is rooted in the fact that the marginal costs of repurposing the cascading material are lower than the cost of virgin material (including its embedded costs and externalities). Capturing a multitude of possible value streams (rather than just one) associated with a specific consumer item can also improve companies' economic resilience. Examples include:

- Manufacturing processes for food and beverages tend to result in sizable flows of valuable, unused materials that are rich in nutrients. While these are partially cascaded today, for example as food for animals, there is significant additional economic potential to be captured. For example, widening good practice to more geographies and value chains, and identifying more economically valuable cascades for today's process 'rejects' to cycle through.

- Discarded food has huge potential as a source of value, whether as energy, nutrients, or carbon, if it can be efficiently collected and sorted. A number of municipalities already promote the process of anaerobic digestion or composting, although the practice is still sub-scale in most markets.

• Fully circular systems would also capture the value of human and animal waste as an agricultural input that helps replenish both macro- and micronutrients.

• Similarly, transforming cotton-based clothing into fibrefill for furniture, and later into insulation material before safely returning it to the biosphere. (provided no harmful additives or dyes have been used in the production process).



Power of pure, non-toxic, or at least easier-to-separate inputs and designs

The power of this fourth major lever is its ability to enhance the impact of the first three by rendering them 'fit for onward use'. Beyond the need to enhance product life and the ability to cycle tightly and many times, a product's true end-of-life stage needs to be anticipated in the choice of materials. 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 single product (e.g., PVC labels on PET bottles), or because they are collected or handled without segmentation or regard for preserving their purity and quality (food waste discarded via mixed municipal waste collection, for example).

As with durables, designing fast-moving consumer goods so they can be easily separated into their material components is an important contributor to enhancing the value that can be extracted in one or more of the circles. Unlike pure wool, which can be re-spun with hardly any loss of quality, fabric blends are still difficult to separate for recycling without degradation in value.

In a similar vein, optimising product and packaging design in conjunction with sorting and collection systems creates an ensemble suitable for full-value recovery. Designing packaging to fit both a product and its use environment (in which it will also be discarded) makes sorting, cascading, and recycling much more cost effective. This is not a trivial task with increasingly complex packaging technology, particularly within the retail food sector. Differences also exist between packaging for on-the-go products versus at-home products. Both of these differ, in turn, from packaging for food items to be sold at a specific event, which typically offers a more controlled environment for collection. Some companies, when selecting packaging for different markets, systematically integrate the nature and quality of end-of-life systems in those markets into their decisions.

2. From linear to circular
Continued

Coming full circle, **regeneration** activities round out a system. Preserving and rebuilding the long-term resilience of the agricultural system and the 'systems services' provided by the larger biological system in which agriculture is anchored are the foundation for creating value from these assets in the future. While biological systems services are 'externalities' that do not show up on the balance sheet of an individual business, they do play essential roles such as providing clean water, pollinating crops, and decomposing and detoxifying waste. Damage to these services is of increasing interest to food, textiles and beverage industries, as it can diminish harvest yields and ultimately limit the resilience of a business and its medium-/long-term growth. Puma's initiative to publish 'Environmental Profit and Loss' reports show that some industry players have started to integrate this factor in their core strategy, and the PPR Group who own the brand have announced they will be extending the methodology to all of their brands by 2015.

How it works up close
Examples of circular opportunities for fast-moving consumer goods

3

Investigating how circular businesses can extract more value than the linear economy in three parts of the consumer goods industry: making use of food waste and food processing by-products, reducing the material impact of apparel without reducing consumer choice, and getting to grips with beverage packaging.



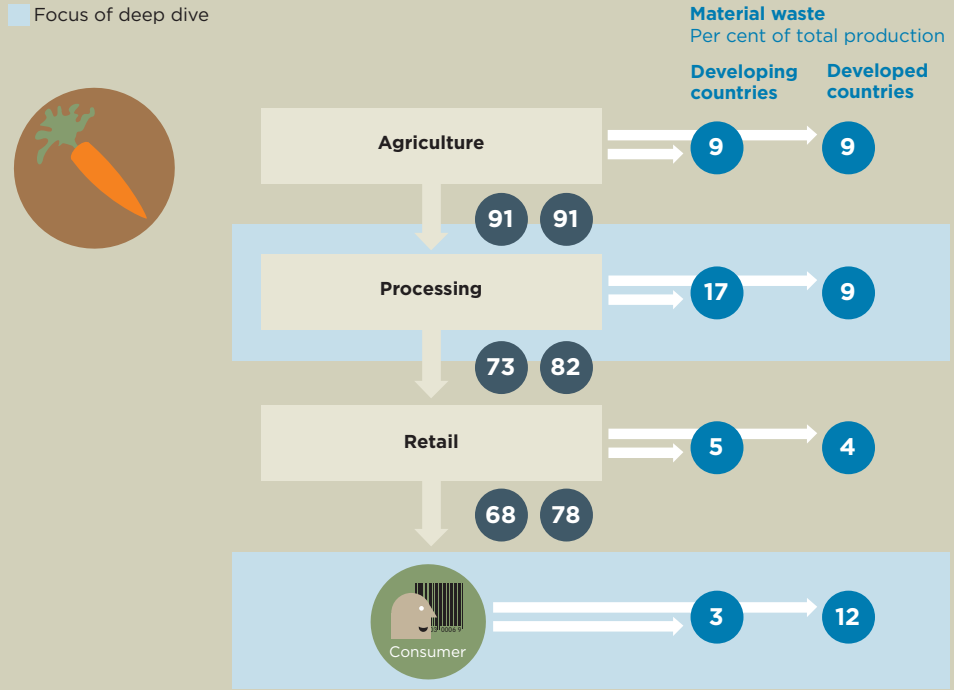
3. How it works up close
Examples of circular opportunities for fast-moving consumer goods

To investigate how circular business models can provide new opportunities for growth in consumer goods, we explored three categories for evidence that this approach can generate both incremental profits and substantial material savings. These categories were selected for their relevance as measured by the share of consumer spending they represent, the resources they use, and the waste they generate.

Food and beverages. At global sales of ~ USD 8.3 trillion per annum, including both fresh and packaged formats, food is the largest fast-moving consumer goods category. Food is an indisputably fundamental human need, and is intimately associated with identity and culture. We have chosen to concentrate on two of the most problematic aspects of food, namely food losses in manufacturing and food waste at the consumption stage (both in households and food service) (Figure 5).

Our question here was whether there is a way to use circular principles to create a profitable business that values this waste. We recognise that food waste at the agricultural level is also substantial and should be tackled, but it is outside the scope of this report.

FIGURE 5 **Main sources of food waste — manufacturing and consumption**



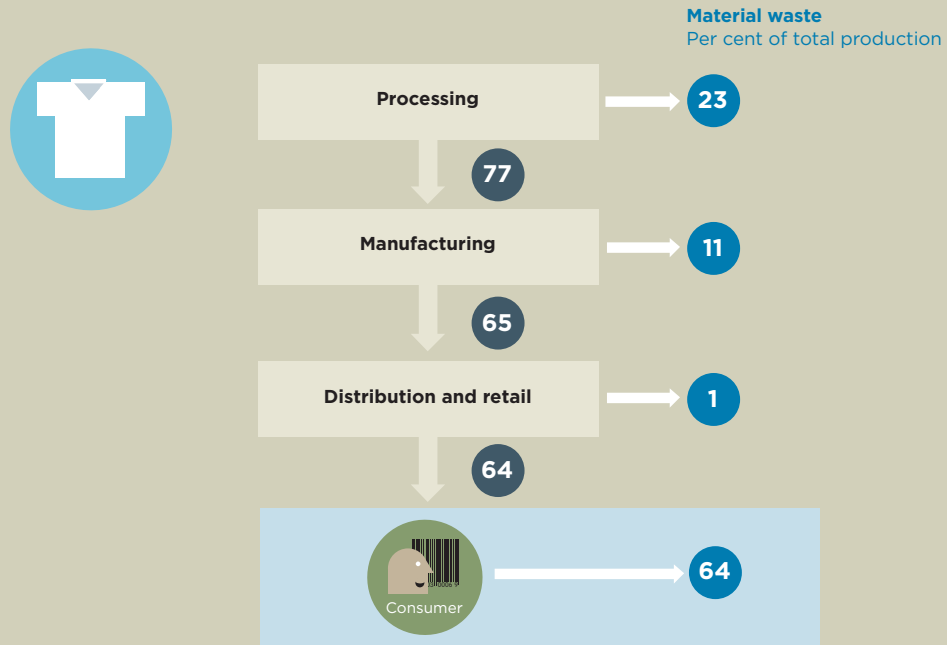
SOURCE: FAO 'Global Food Losses and Food Waste – Extent, causes and prevention', Rome 2011; Ellen MacArthur Foundation circular economy team

Clothing. The second-largest category of spend within the consumer sector is clothing and footwear, another core human need, accounting for sales of USD 1.8 trillion annually. The vast majority of the clothing industry currently operates an entirely linear consumption model, with a large proportion of all items ending in landfill (and—in high-income countries—after a limited useful life at the back of a wardrobe). The consumption stage accounts for by far the largest share of waste in the clothing category (Figure 6).

Here, we explored whether there are profitable circular business models that allow for high levels of reuse and cascading of clothing.

FIGURE 6 **In clothing, waste occurs mainly at the end of life — UK clothing example**

Focus of deep dive



SOURCE: WRAP 'Valuing Our Clothes', 2009

3. How it works up close
Continued

Packaging. Given its central role in the consumer goods industry, we also conducted a deep-dive analysis of packaging to better understand the potential alternatives to 'one-way' packaging. The question here was whether circular packaging models could be profitable for manufacturers, allow for a better consumer experience, and deliver significant material savings.

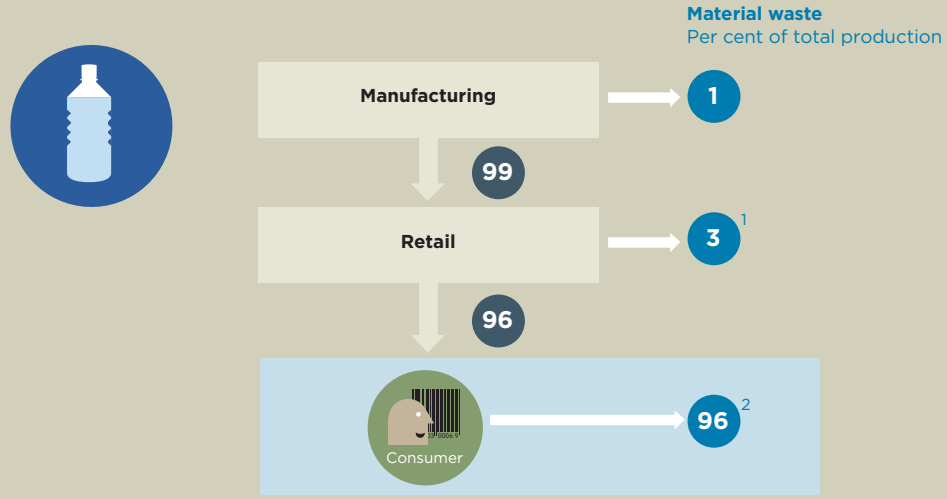
To draw a meaningful comparison, we chose to study beverage packaging as it is a major product segment (beverages account for sales of USD 2.4 trillion annually), a large amount of packaging material is wasted (especially at the consumption stage), and comprises a wide range of distribution models, packaging types, and materials (Figure 7).

These categories represent about 80% of the world's total expenditure on fast-moving consumer goods[64].

For each of the three areas, we first outline whether more circularity is desirable and then discuss the evidence for 1) the viability of business models, 2) examples of circular business models already in operation today, and 3) what needs to happen for larger-scale adoption of the circular business model.

FIGURE 7 **In packaging, waste occurs mainly at the end of life — Plastic bottle example**

Focus of deep dive



1 Assuming the retail beverage food waste is 60% of the overall food waste
2 This includes all packaging at end of life that will then either be recycled, incinerated or landfilled

SOURCE: FAO 'Global Food Losses and Food Waste – Extent, causes and prevention' Rome 2011, Ellen MacArthur Foundation circular economy team

1. Food and beverages

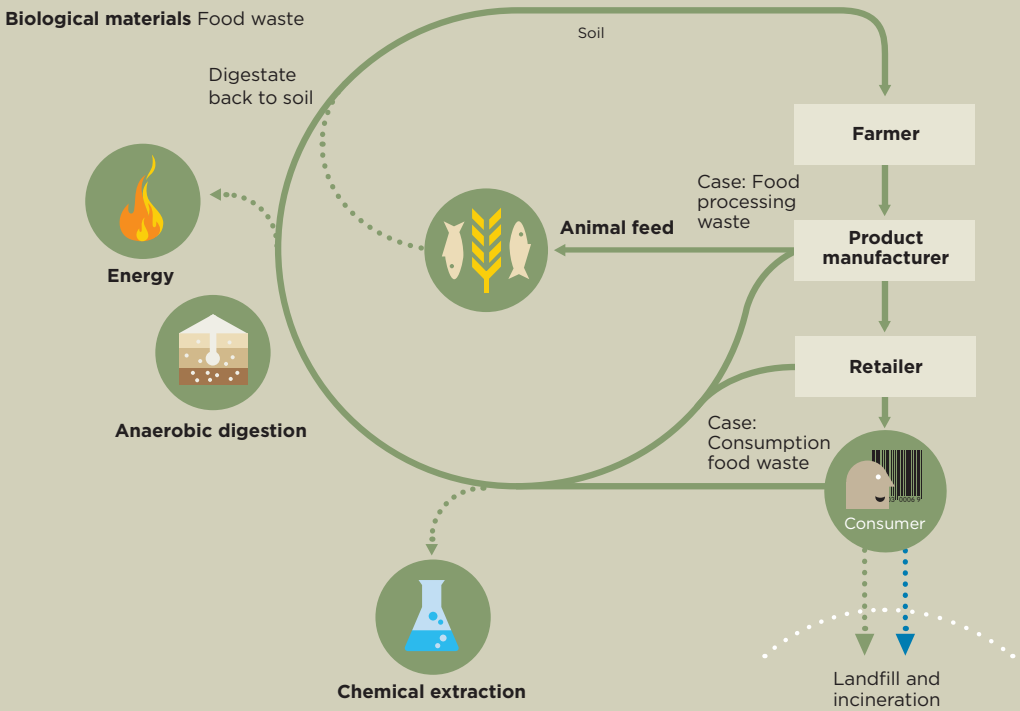
Our analysis shows that it is possible to build profitable circular businesses that make good use of the food waste that is generated in the consumption and food processing stages of the food and drinks value chain (Figure 8).[65]

At the consumption stage, we analyse the options to deal with the *mixed food waste* created in the later stages of the supply chain—in retail shops, households, and food service and restaurants. For this 'consumption waste', we estimate that in the U.K. increasing circularity could generate profits of USD 172 per tonne—providing a significant economic opportunity for both municipalities and investors[66].

At the food processing stage, we investigate the potential for circularity in industrial food processing, where losses mostly take the form of *by-products*—such as brewer's spent grains from beer production or orange peel in juice production—or streams conventionally considered to be entirely without value, such as grey water resulting from screening, filtering, and pressing. For brewer's spent grains, more widespread cascading to feed for livestock or fish, and recycling through anaerobic digestion could create a profit of USD 1.91 per hectolitre of beer produced.

After outlining current costs of food waste, we describe methods for extracting more value and realising material savings in a circular way, and how they might be put into practice more widely.

FIGURE 8 **Food and beverage – retail, household, and production material flows**



SOURCE: Ellen MacArthur Foundation circular economy team

65 Complete food and beverages lifecycle is understood to include agriculture, manufacture, packaging, distribution, retail, transport, storage and preparation, and waste treatment and disposal. The focus is on households but extends to retailers and the hospitality sector.

66 Our estimate shows that it could represent a USD 1.5 billion opportunity for the UK

3. How it works up close
Continued

Why is food waste important?

While daily amounts of 'post-consumer' waste are small, unconsumed food and drinks add up to a yearly average of USD 770 per U.K. household, or USD 19 billion in annual spending in the U.K. on food and drinks that could have been consumed but are instead discarded. In the retail segment, the average value of a tonne of food discarded in the U.K. due to spoilage, leakage, etc. is estimated to be USD 2,700 in forgone sales value. This adds up to an estimated value of USD 970 million for U.K. retailers[67].

This lost value, recently in the spotlight as a result of a form of activism known as 'dumpster diving', is only part of the story. In the U.K., as in other developed countries, most of the 8 million tonnes of annual waste from households plus the 4 million tonnes from supermarkets and restaurants go into landfill, incurring ~USD 1,230 million in disposal costs. Beyond the disposal charges incurred by households and businesses, many of the world's cities and densely populated areas face the risk of running out of safe opportunities for landfill disposal. At the current rates of accumulation, referred to as 'arisings', of food and other waste, the U.K.'s designated landfills will be full by 2018. Furthermore, when landfilled, food waste does not decompose benignly but incurs environmental costs by emitting methane. Decaying food waste emits an estimated 130 million tonnes of CO_2e[68] globally, about 0.35% of total global GHG emissions—small but entirely preventable. In landfill, food waste also contributes to the formation of leachate, a cocktail of liquids that seeps from solid waste and can pollute surface and ground water.

Analysing the landfill fraction that is food waste at a molecular level would reveal the presence of the valuable soil nutrients nitrogen (N), phosphorus (P), and potassium (K) that are the three most widely applied fertilisers. Locked up in the landfill, these nutrients are practically useless, while using them as a part replacement for mineral fertiliser, their value would have amounted to ~USD 67 million each year in the U.K. alone.

Despite the efficiency imperative, many food and beverage manufacturers' production processes generate biological by-products that have considerable value. Take beer. The saying that 'beer is liquid bread' holds a grain of truth: beer is typically made from cereals with a high nutrient content. Though beer does retain some nutritional value, much is filtered out during brewing and remains in a solid by-product known as 'brewer's spent grain' or BSG. While BSG is relatively high in protein and fibre—and thus a good a feed supplement for animals—it also has a high moisture content and typically rots within a month. Some brewers offer BSG to local farmers, but anywhere from 10 to 50% ends up in landfill.

MYTH
Collecting food waste from households isn't worth the trouble

Reality: With anaerobic digestion (AD) technology, a business can extract benefits that far outweigh the costs

Food waste is valuable! With anaerobic processing, it turns into energy and fertiliser which can generate a value of ~ USD 60 per tonne (see example for U.K. below). Separate collection can be implemented at little additional cost, as the overall waste volumes don't change. Diverting food waste to the AD process has many additional indirect benefits, such as avoiding GHG emissions in landfill, increasing the value of the residual (non-food) waste stream in incineration, and returning nutrients to the soil. (For more information, see the sidebar on anaerobic digestion.)

MYTH
Households cannot be convinced to separate food

Reality: Italy has achieved high collection rates for years; most people respond favourably

In southern Italy, some municipal collection programs for household food waste were already achieving capture rates close to 80% back in 2002. Once systems are in place, public opinion is generally favourable.

67 Business benefits of resource efficiency, Department for Environment, Food & Rural Affairs, U.K., 2007, in: Waste arisings in the supply of food and drink to households, WRAP, 2011

68 WRAP, Waste arisings in the supply of food and drink to U.K. households, 2011, Ellen MacArthur Circular Economy Team Analysis

69 The hierarchy used in the U.K. has five levels: reduce the amount of material used, prepare for reuse, recycle, recover other value, and, as a last resort, dispose

70 WRAP; Case studies, Courtauld Commitment 2, 2012

71 www.save-food.org. Article title 'EU-FUSIONS project examines the entire food chain'

72 SealedAir, Enhancing Sustainability by Preventing Waste

73 Ministry of Agriculture, Forestry and Fisheries, Japan, 2010

Avoiding food losses and food waste

Avoiding food waste should be a priority. Prevention has also been enshrined as the most valuable strategy for waste in the 'waste hierarchy' (Lansink's ladder), which was included in the European Waste Framework Directive in 2008, and enacted into law in the U.K. in 2011.[69] It is also advocated by the U.S. Environmental Protection Agency and government agencies in many other countries, from Australia to Oman.

Current management practice to reduce food waste is a logical extension of lean production systems, which aim to eliminate all product or service features that do not create value that consumers are willing to pay for. In food retailing, the main source of preventable waste is the fresh produce department, which is therefore the focus of constant efforts to stock the precise quantities demanded and maximise shelf life. Both solutions typically require optimisation of the supply chain back to the manufacturer and growers. While median losses through spoilage in fresh produce are 6 – 8%, best-practice retailers have pared this figure to 3 – 5%. Data tracking and analysis play a critical role in achieving results that are twice as good as competitors' performance. As the 'last mile' before the consumer, retailers typically have access to extensive shopping data, which leading firms are using to improve waste avoidance. Shopping data helps amongst other things to improve demand forecasts, which benefits all of the participants in a given food supply chain. With this approach, U.K. grocery retailer ASDA's 'Faster Fresh' initiative increased the shelf life of nearly 1,600 chilled products by an average of one day.[70] In Norway, For-Mat is a collaborative effort by the government and Norwegian grocers aimed at establishing better data on retail-level food waste so as to lay a solid foundation for effective waste prevention measures. On a larger scale, the EU project FUSIONS[71] also aims to bring together all contributors along the food chain to collect data and start concerted efforts to avoid food waste.

Another set of methods for increasing shelf life is 'active and intelligent packaging', including, for example, packaging food in a protective atmosphere.[8] Working with poultry supplier Moy Park, ASDA adopted new packaging that increased shelf life from 8 to 10 days. Similarly, a new packaging film for potatoes enabled ASDA to slash potato waste by 50%. A study by Sealed Air found that changing the supply chain for minced meat from traditional in-store meat grinding and packaging to grinding and pre-packaging in a protective atmosphere in a central facility could extend shelf life from 1 to 3 days to 7 to 21 days, reducing retail losses from 7 – 8% to 2 – 3%.[72]

Packaged fresh food that is still perfectly fit for consumption often becomes harder to sell as the best-by date gets closer, especially since consumer confusion may exist over best-by versus sell-by dates. In most markets some form of active discounting moves these products off the shelf before the best-by date expires. In the U.S., salvage grocery and dollar stores have been joined in the past few years by grocery auctions in selling packaged food products past their best-by date at a deep discount. In 2012, the European Parliament called on the European Commission to encourage the discounted sale of food close to its expiry date. In some geographies and situations, however, retailers have indicated that consumer acceptance for such products is low. An alternative avenue with goodwill benefits has developed amongst retailers, hospitality businesses, and food service companies in the form of donations to food banks and pantries such as Second Harvest and Die Tafel.

A further solution—albeit of lower value—is to process food waste for animal feed. In Asia, processing food waste into animal feed is promoted to avoid landfilling and decrease dependence on imported food. The Japanese government promotes the 'Ecofeed' initiative to convert more food waste to animal feed as part of a move to increase overall self-sufficiency in animal feed. Recycled food costs around 50% less than regular feed.[73] However, some markets, such as the U.K., prevent the use of food waste for animal feed as a precaution against the spread of disease. Such restrictions apply mostly to food waste from households, supermarkets, and the hospitality industry, which may contain meat, but do not apply to food processing companies that can guarantee that food waste streams are free of animal by-products.

3. How it works up close
Continued

Anaerobic digestion—A zero-waste technology

Anaerobic digestion (AD) is a process in which microbes digest organic material in the absence of oxygen. The process creates two distinct products: biogas, a mix of ~60% methane and ~40% carbon dioxide, and a liquid or solid residue, the digestate.

Biogas: To fully extract the value of the biogas created in the AD process, the methane can either be used directly in a nearby industrial boiler or for district heating purposes, burned to produce electricity and heat in a combined heat and power plant (CHP), or cleaned and fed into the gas grid.

Digestate: Anaerobic digestate made from food waste can be used as fertiliser for agriculture as it has a high nutrient value. In fact, AD digestate retains the same nutrient content (NPK values) as the ingoing food waste, and is characterised by high available nitrogen (estimated at 80% for food waste digestate), making its effect comparable to mineral fertilisers. In this respect, it differs from compost, which contains mainly slow-release nitrogen. According to the IEA: '... digestate is a very useful organic fertiliser that can be used to offset the financial as well as the environmental costs associated with the use of mineral fertiliser'[75]. This assessment is confirmed by Dr. Rafaella Villa from Cranfield University: 'The value and the quality of what comes out of the digestate is of very high quality and people should take more advantage of that'. Further research on nutrient availability and impact is on-going, as digestate also contains micronutrients not present in commercial mineral fertiliser. Digestate can be used whole, separated into a liquid and solid fraction, or processed into pelletised organic fertiliser. These options, particularly pellets, would make it easier to customise and distribute digestate over long distances. Cheaper technologies to process digestate into a standardised and transportable product are under development since current techniques are still relatively expensive and energy intensive.[76]

Which circular models work best for *food consumption waste*?

In the food and drinks sector, the biggest source of business value is to process food waste by directing it into cascaded uses.

Critically, to extract the maximum value, food needs to be collected from households, retailers, and restaurants and food service organisations as a separate stream, i.e., not mixed with other waste. For this, effort must be made in advance to design product/package combinations for ease of separation and to avoid toxic substances.

In some cases, specialty cascades can be formed by segregating specific food preparation by-products into a type-specific value stream. A prominent example is cooking oils and fats, which can be used to make biofuel. This category includes frying fats, fat from oil traps, and even fat extracted from mixed food waste.[74] In the U.K., companies such as Brocklesby and ReFood collect food waste and frying oils from retailers and fast-food outlets and producers, and then process the fats and oils into biodiesel feedstock. Robert Brocklesby summarises his company's approach quite simply as: 'We look for additional value from specific food waste streams and add further value to the chain. He also mentions that 'Companies increasingly expect to be paid for their waste' as its value is being discovered.

Another interesting opportunity is the extraction of specialty chemicals from food waste, such as, for example, pectin from citrus peel. For mixed food waste, the biggest opportunity is to recover energy and create fertiliser: the residual value of food can be economically 'harvested' for both purposes through the anaerobic digestion (AD) process (see sidebar).

74 This practice is well established in Germany and the Netherlands and beginning to develop in the U.K.

75 Utilisation of digestate from biogas plants as biofertiliser, IEA Bioenergy 2010

76 Note that even if digestate does not fulfil quality standards that allow sale as fertiliser, generally landfill cost is much lower than for raw waste or zero, as digestate is classified as an 'inactive waste' and can even be used as landfill cover.

Recovering nutrients from domestic and industrial waste water

Soil-enriching nutrients can be recovered from all types of waste water, not just from food processing. In 2001, Swiss analysts estimated that, if we could capture 100% of the nutrients present in global household sewage, we could recover nearly 30 million tonnes of nitrogen, 5 million tonnes of phosphorus, and 12 million tonnes of potassium—the all-important NPK group of nutrients. A more recent analysis conducted by Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia found that—for a city of four million people—the total value of the carbon, ammonia, and phosphorus recovered would be USD 300 million per annum.

Several countries have already started exploiting the potential offered by domestic waste water, with both governments and academia mainly focusing on phosphorus. The Netherlands is a forerunner in the field of phosphorus recycling and Sweden has set an interim target to recycle at least 60% of phosphorus compounds in sewage for use on productive land by 2015. At least half of this is to be used on arable land.[79]

The world's largest municipal nutrient recovery facility[80] was opened in the U.S. in May 2012 as a public-private partnership between Clean Water Services and Ostara Nutrient Recovery Technologies, Inc., in Hillsboro, Oregon. The facility uses Ostara's Pearl® Nutrient Recovery Process to capture phosphorus and nitrogen from waste water and transform them into an environmentally friendly, slow-release fertiliser, which is sold locally and throughout the country. The combination of cost savings and revenue are projected to pay for the cost of the USD 4.5 billion Rock Creek Nutrient Recovery Facility in six years.

Most of the processes employed worldwide recover phosphorus and nitrogen in the form of struvite (magnesium ammonium phosphate) and/or calcium-phosphate pellets. While processes exist that can recover 90% of phosphorus, only a fraction (5-15%) of the nitrogen available in waste water can be recovered through phosphate-based precipitates. Further technologies to recover multiple resources need to be developed.

MYTH
Burning waste is cheaper than separating it and processing in an AD plant; and it's also 'green' as it is an alternative to fossil fuels

Reality: AD is less expensive, creates more energy, and allows the extraction of fertilising nutrients

In countries where municipal waste is not separated, mixed waste is often burned in high-temperature incinerators to generate energy. On balance, however, separating out food waste is more economical, as separate collection can be realised at a very low incremental cost, and anaerobic digestion of food waste is less expensive than incineration.[77] Environmentally, AD is consistently found to be the better option for recovering energy from food waste, as it has the triple benefit of avoiding landfill emissions, generating energy, and returning organic material and fertilising nutrients to the soil. For these reasons, many countries, such as the U.K., have ranked AD above composting and incineration in the waste hierarchy for food waste.[78] A further factor favouring the AD solution is that wet organic waste, such as food waste, reduces the efficiency of modern incinerators, leading to reduced energy generation and reduced revenues.

77 W. Edelmann, K. Schleiss, Ökologischer, energetischer und ökonomischer Vergleich von Vergärung, Kompostierung und Verbrennung fester biogener Abfallstoffe, 2001, Comissioned by the Swiss Federal Office of Energy and the Swiss Federal Office for the Environment

78 Department for Environment, Food & Rural Affairs, U.K., Waste hierarchy

79 Summary of Government Bill 2004/05: 150 available at http://www.government.se/content/1/c6/06/69/79/80a58d03.pdf

80 http://www.ostara.com/news/news-releases/2012/clean-water-services-and-ostara-nutrient-recovery-technologies-open-worlds-l

3. How it works up close
Continued

What is it worth?

To estimate the value of processing food waste through anaerobic digestion, we can take two perspectives: that of a municipality dealing with a mixed stream of household and commercial waste, and that of an investor who wants to generate and sell energy and fertiliser. Processing food with AD is attractive from both perspectives: it mitigates the problem of steeply rising landfill costs burdening municipalities' budgets and offers an attractive business model (Figure 9). In assessing the economics, we looked at the full value created by: 1) avoiding the cost of landfill and 2) receiving revenues from subsidies for renewable energy generation in a market like the U.K.

Municipalities today regard organic waste management mostly as a cost, but it can also be an attractive source of revenue. In the U.K. the charge for landfill amounts to USD 102 per tonne, up from USD 40 five years ago. A similar picture arises both in low- and high- income countries: landfilling in Brazil costs around USD 20 – 25 per tonne; in Israel, it costs USD 13 per tonne, an increase by a factor of five since 2007.[81] In May 2012, the European Parliament voted in favour of legislation to reduce landfilling of organic waste, with the aim to reduce it to zero by 2020.[82] In South Korea, landfilling bans for food waste went into effect in 2005.[83] In addition to raising landfill charges, less to increase municipal revenue and more to discourage dumping of materials that can be put to other uses, many governments have introduced renewable energy incentives in response to growing greenhouse gas emission rates. In the U.K., for example, AD profits from a 'feed-in-tariff', an incentive designed to stimulate renewable energy generation as well from a guaranteed minimum price for supplying electricity to the grid to give investors security for long-term projects. We estimate that processing food waste with anaerobic digestion instead of landfilling could create an operating profit of up to USD 172 per tonne of food waste. This profit breaks down into the following value components: one tonne of food waste can create electricity worth USD 26, heat worth USD 18, and fertiliser worth USD 6. The feed-in tariff subsidy for renewable energy is worth USD 64. In addition, landfill costs of USD 105 are avoided. This is netted against a sorting and processing cost of USD 43 per tonne.

The assumptions underlying this profit calculation reflect a developed system in which experience has improved performance versus today's average in the following ways:

• Load factor. An important parameter in the economics of an AD plant is the load factor, i.e., the time the plant operates per year. We assume a 95% availability rate for very good operations; ~90% is average. This has no impact on the revenue per tonne of food waste but reduces the processing cost by 5%.

• Economies of scale on component prices. If plants are rolled out on a large scale, operators will benefit from lower prices. We assumed a total reduction in investment costs of 25% compared with median values found in the U.K. today.

• Innovation. Advances in AD microbiology could allow a higher throughput. For example, Schmack Biogas has developed a new bacteria strain that can double the digestion rate.[84] This would reduce the required volume of an AD plant, reducing the estimated investment by a further 25%.

• Efficiency gains. General improvements in operational efficiency account for a 15% reduction in operating cost versus median values today.

• Revenue. Here we assume that the digestate that is currently given away to farmers for free can command a price equivalent to the value of its content of NPK fertiliser nutrients of USD 5.60 at current wholesale prices (and allowing for additional cost of transport to farms).

The conversion of food resources from household, retail, and hospitality landfill streams could represent an income stream of USD 1.5 billion in the U.K., based on a total collected stream of 9 million tonnes. This assumes that all municipalities operate a separate collection program for food waste at the consumption level, and then manage to capture 90% of the waste volume created in retail and hospitality and 70% of the food waste created in households.

81 Ministry of Environmental Protection, State of Israel

82 European Commission

83 Taewan Jeon, National Institute of Environmental Research, South Korea

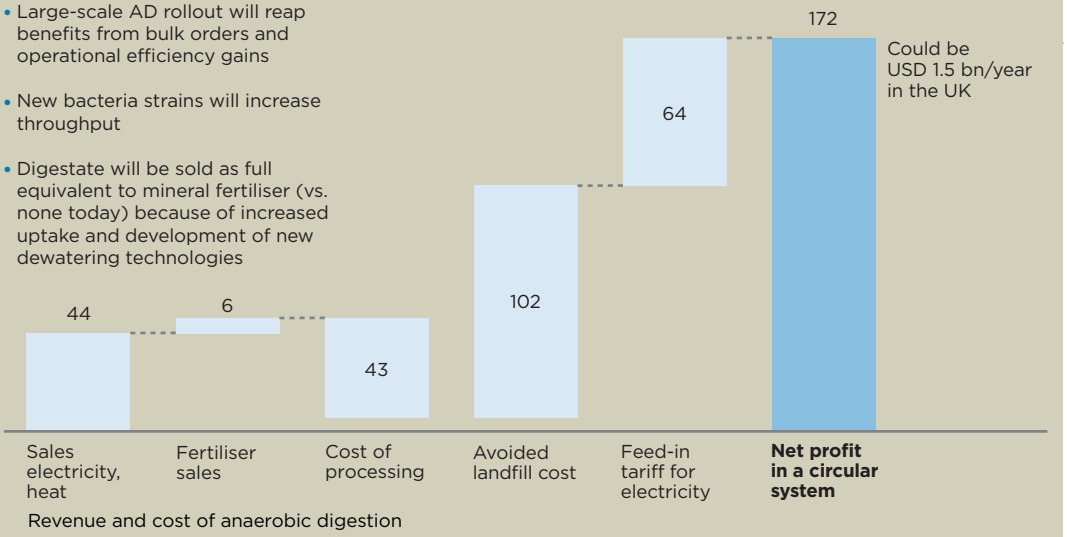
84 Schmack Biogas, Methanos

85 National Grid: The potential for renewable gas in the UK, January 2009

FIGURE 9 **Shifting to a circular system for food waste could create profits of $172 per tonne of food waste**

Profit from going from a linear system to circular[1]
USD per tonne of food waste, UK, 2012

Assumptions
- Large-scale AD rollout will reap benefits from bulk orders and operational efficiency gains
- New bacteria strains will increase throughput
- Digestate will be sold as full equivalent to mineral fertiliser (vs. none today) because of increased uptake and development of new dewatering technologies



1 Fertiliser: wholesale price, 2011. energy prices 2012, landfill price 2012
SOURCE: Ellen MacArthur Foundation circular economy team

What's working well today

Anaerobic digestion is already in use around the world and can be rapidly scaled up.

• In Germany, biomass generated 119 TWh electricity in 2011, around 5.2% of the country's gross power generation. Worldwide capacity in 2011 was around 72 GW.[86] In developing countries, the biogas generated in micro-scale AD facilities from food waste and animal manure is widely used as a clean cooking fuel. Since 1982, India has had a national program in place to promote small-scale anaerobic digestion for cattle manure that has resulted in 4 million small-scale installations as well as some large AD plants for power generation.[87]

• In the U.K., rapid scale-up has occurred in the last few years, and the transition is still in progress. The number of anaerobic digestion plants operating in the U.K. has rocketed from two in 2005 to 214 in 2011 with a total generating capacity of 170 MW according to a new study by WRAP[88]. WRAP reports that 26 of these plants process mainly segregated food waste, on a commercial basis[89] (the remainder process sewage, agricultural waste, sludge, and industrial food and beverage production wastes as feedstock). AD is also attracting the interest of investors. Tamar Energy, for example, plans to build 44 AD plants in the U.K., with a total capacity of 100 MW by 2017.

Amongst AD plants looking at using post-consumer food streams, interest has also increased in upgrading the resulting biogas and feeding it into the gas grid. At present, only two such sites are in operation in the U.K., one of which is waste-fed[90]. According Marcus Stewart, Future Distribution Networks Manager at the National Grid, the company has received 150 inquiries for gas upgrading, which have already resulted in 14 concrete projects. The National Grid runs about half the gas network in the U.K. and currently has a target for 2020 of producing 7 TWh from biogas.

MYTH
AD is just a 'cottage industry'

Reality: Anaerobic digestion is a decentralised technology; professional operators can realise economies of scale

Since farmers have used small-scale AD plants for decades and many developing countries even have household-sized plants, AD has long had the image of 'just a backyard solution'. While it is true that the optimal size of an AD plant is smaller than traditional technologies (1 – 2 MW versus 1,000 MW for a large coal or nuclear plant), AD benefits significantly from economies of scale, optimised logistics, and rigorous process control. Investors are already rolling out projects for large fleets of plants. And in its report 'The potential for renewable gas in the UK', National Grid points out that cleaning and injecting biogas into the gas grid can help overcome the lack of co-location opportunities that AD operators face when looking for smaller, local commercial avenues for their energy output.

86 Statista, Biomass, Biogas statistics

87 Indian Ministry of New and Renewable Energy

88 WRAP: Anaerobic digestion infrastructure in the U.K., 2011

89 Includes both industrial and non-industrial wastes

90 WRAP, Anaerobic digestion infrastructure in the U.K.: September 2011

3. How it works up close
Continued

How can we make it happen?

The most important change required to build a circular economy around food consumption waste is to significantly increase collection as a separate stream. Examples of this and every other change required to operate a profitable system have already been implemented in individual regions today—including awareness and information campaigns and financial incentives and disincentives.

Collecting separate streams of food waste. The main driver for high collection rates is a convenient and simple system with door-to-door collection. High shares of food waste generated by households can be captured at no significant extra cost—as trials in the U.K. and experience in other countries have shown—provided collection is well designed. Separate food waste collection can be implemented at little to no additional cost if the system is optimised, i.e., assuming the total waste volume remains roughly the same, different types of waste can be collected on alternate trips. In the long run, the cost for municipalities can even be decreased.[91] Experience in Italy also shows that capture rates over 70% are possible within a few years, with the purity of the collected organic waste at around 97%.[92]

Separate organic waste collection is also emerging as a commercial opportunity in developing countries, where comprehensive waste collection is still rarely offered by municipalities and instead mainly handled by the informal sector.

Increasing consumer participation in refuse separation schemes. Food is an emotional subject, which creates barriers to increasing participation in food waste separation schemes. These mindset barriers range from general squeamishness about food waste and the misperception that separation is not worthwhile, to 'lack of space in the home' for several refuse bins to support separation. As different programmes around Europe show, such barriers can be successfully addressed with information campaigns, incentives, and collection systems that focus on convenience for households.

Using regulation to channel food waste to the highest-value uses. Waste management regulation governs the options for owning food waste streams and extracting value. In adapting regulation to assist the transition towards more circularity and hence higher resource productivity, governments need to strike a balance between guiding waste towards the highest value use and protecting citizens and the environment. Successful recent examples of regulatory action include taxes on landfill, incentives for renewable energy, and standards for digestate.

Being smart about synergies and location. Optimal size and siting of AD plants are important aspects of the economic case, as is the configuration of a secure feedstock supply and its delivery to the plant. As AD plant economics depend on maximum operating times, securing a large source of organic waste, such as from a city or a factory, reduces the risk of downtime. Also, since both feedstock and digestate have a high water content, transport costs are significant. Moreover, if the methane produced is used in a CHP plant, the heat needs to be used locally, suggesting co-location with industry or a residential area that is set up for district heating. As James Russell of Tamar Energy notes, 'AD is essentially a logistics business'.

Pursuing necessary technology innovation to make digestate a more versatile product. Additional technical improvements and innovation are needed to realise the full value of food-based digestate. To minimise ammonia emissions, digestate needs to be applied with equipment that inserts it into the topsoil rather than on the surface. This may require a combination of local innovation and equipment imports from countries where using digestate or manure slurry as a replacement for mineral fertiliser is already commonplace, e.g., Germany. In countries where farms are far from urban centres, technology is needed to reduce the water content of digestate, as dewatering is currently uneconomical (at least when no surplus heat is available). The current economical radius for delivery of wet digestate is estimated to be 30km.

91 In Italy, source separation with door-to door collection was introduced in the mid-1990s, reducing costs for many municipalities. Residential services to provide 'source separated organics' (SSO) collection is now available to 24 million people in Italy in more than 2,500 municipalities. (Source: Source segregation of biowaste in Italy, Plastic Bag Ban And Residential SSO Diversion, Christian Garaffa and Rhodes Yepsen)

92 Experience in southern Italy shows capture rates between 38% and 78%, with a median of 57.5% in 2002) (Source: Source segregation of biowaste in Italy, Plastic Bag Ban And Residential SSO Diversion, Christian Garaffa and Rhodes Yepsen.)

Innovative solutions around digestate distribution are emerging, however. One example of convenient distribution to small farms is a cooperative in Germany that uses AD to run two biogas plants and has implemented a self-service point resembling a petrol station where farmers can pick up wet digestate after identifying themselves via an RFID tag.[93]

Investment requirements. The total capital expenditure required to treat all of the food consumption waste in the U.K. would be around USD 1.4 billion. Assuming an average AD plant capacity of 70,000 tonnes, the U.K. would need 136 AD plants.

Large plants have capacities of up to 120,000 tonnes, and digesters and CHP plants are modular, making them scalable. Yet although the costs of grid connections and administration favour larger plants, technically feasible transport distances for feedstock and digestate effectively limit plant size. This might create opportunities for smaller players such as cooperatives. Currently, farmers cooperate on AD projects, but more for farm wastes, not post-consumer food matter.[94]

In the next section, we describe the opportunities for extracting maximum value from the by-products of industrial food processing.[95]

How do food and beverage by-products cascades work?

Valorisation of by-products within the food and beverage industries is well established in sub-segments but further efforts could lead to even greater material savings. For example, the beer industry has found ways to capture the economic value of by-products and generate significant material savings. Along with beer, breweries (like distilleries and wineries) produce a large volume of by-products in liquid and solid form. The main by-products and process wastes in beer-making with an economic value are spent grains, yeast, and grey water. While highly dependent on local circumstances, analysis shows that, in Brazil, extracting the maximum value from the solid by-products could potentially generate an additional profit of USD 2 per hectolitre of beer produced on

Renewable energy incentives around the world

In the U.K., the incentives for developing renewable energy sources play an important role in making AD attractive to investors. Anaerobic digestion plants with electricity generation profit from the feed-in-tariff 'FIT' of USD 0.16 per kWh of electricity produced. If power is sold to the grid, the supplier can choose to sell it at the market rate or at a guaranteed 'export' tariff of USD 0.07. For gas-to-grid, as well as for heat generated in small-scale AD plants, the renewable heat incentive (RHI) is available. Currently, AD plants using food waste would operate around the break even point without incentives, future development will improve this picture.

This business model is portable to other countries. Incentives for renewable energy generation are now available in 96 countries around the world, in many countries in Europe, but also in China, Brazil, Mexico, the U.S., Canada, Argentina, Peru, and Turkey. Different mechanisms exist, such as regulatory policies like feed-in tariffs, obligatory biofuel mandates, tradable renewable energy permits, and fiscal incentives such as tax-breaks and public financing. Many countries offer a range of measures.[98] Municipal authorities and investors should review the range of renewable energy incentives offered to make sure that they are, in fact, favourable to AD. In addition, anaerobic digestion projects are also eligible for credits in the Clean Development Mechanism (CDM) under the Kyoto Protocol.[99]

93 Agrokraft Streutal GmbH (http://agrokraft-streutal.de/cms/Gaerrest-Tankstelle.30.0.html)

94 Case studies Department for Environment, Food & Rural Affairs, U.K. , Anaerobic digestion strategic action plan

95 The further benefits of fully adopting circular solutions for post-consumer food waste and food processing by-produces are discussed in Chapter 4.

96 U.K. Department of Energy and Climate Change, 2012. For plants of 500 kW-5MW generation capacity

97 REN21 Renewables 2011 Global Status Report, REN21, 2011

98 KPMG, Taxes and incentives for renewable energy, 2012

99 Intergovernmental Panel on Climate Change (IPCC), 2006

3. How it works up close
Continued

top of the margin for the beer itself which ranges from USD 10 to USD 40 per hectolitre of production. The following overview of opportunities for cascaded uses, primarily animal feed, and returning nutrients to the soil is relevant to most food processing by-products.

Water use can be reduced and grey water used to make biogas. Depending on the method and the brewery's efficiency, breweries typically use 4 to 10 litres of water to produce a litre of beer. In Brazil, this adds up to an estimated total of 69 million cubic meters (m^3) of water per year; the global total is nearly 1,200 million m^3. Current industry estimates indicate that using best practices in production can reduce this volume by up to 15%. For example, the Jaguariuna brewery in São Paulo, Brazil, implemented a programme to optimise utilisation of water across all steps of the production process, resulting in a 9% reduction in water use from 2007 to 2009.[100] Breweries use water in two main ways: to wash bottles, which results in wash water that contains almost no organic components, and to make beer, i.e., water used as part of the filtering, screening, and pressing steps. This process water contains nitrogen, potassium, and phosphorus from the grain and hops feedstocks. This means that, in addition to changing the way water is used from the start, brewers can send the unavoidable process water to an anaerobic digestion plant, rather than simply treating and releasing it as treated effluent. In an AD plant, the biological materials in the waste water can be collected and used to generate heat and electricity from methane, either for internal use, hence reducing the brewer's energy bill, or sold to a third party.

Oberon FMR—a private Colorado-based early-stage company—has developed a technology that converts nutrients in the waste-water streams of food and beverage plants into high-quality protein meal (60% protein and only 2% fibre content on a dry matter basis) for the animal nutrition market. The innovation is said to cut the costs of dewatering and disposal, as well as reduce the electric power bill typical at food and drinks companies for aerating waste water, which is full of organic matter.

Brewer's spent grains (BSG): A valuable brewing by-product for cascading. Every litre of beer produced generates roughly a small teacup of brewer's grains (0.14 to 0.2 kg), accounting for more than 90% (dry weight) of the solid waste arising during the brewing process. This currently adds up to 39 million tonnes globally. BSG contains a relatively high proportion of nutrients and is available in relatively large quantities. These characteristics give BSG an economic value that is worth extracting in a cascade to another industry, primarily as animal feed or fish food.

Feed and food production (e.g., livestock feed, fish farming feed). BSG is valuable for its relatively high protein content (25% on a dry matter basis), which among the commonly used feed is second only to soy beans (38% on a dry matter basis). It also has high starch content and is a source of fibre and other nutrients. BSG is a readily available and cheap source of proteins for farmers who generally pick up brewer's grains in wet form directly at the breweries. Anna-Maria Smet, Director of Regulatory Affairs at The Brewers of Europe, an industry association representing more than 80% of the brewery sector, says 'there will always be some farmers knocking at the door of breweries to feed their animals with these grains'.

In addition to dairy cattle and hogs, a new animal feed cascade for BSG could be opening up in commercial fish farming. The largest of these operations by sales are in Asia and actively searching for plant-based substitutes for animal protein in the food that they feed their fish. BSG is a suitable supplement for a number of such fish, e.g., tilapia, catfish, trout, and carp. Arjen Roem, Senior Project Manager at Nutreco, estimates that BSG could account for 2 – 5% of the fish food mix by replacing a blend of corn, wheat, and soya.[101] A majority of the BSG produced in Asia could be used locally when products are targeted more towards fish feed applications. Arjen Roem sees potential particularly in tilapia and catfish, which are projected to be the fastest growers in the fish farm industry, in Asia but also Latin America and Africa. The farming of these species is forecasted to have a global compound annual growth rate of 9 and 12% respectively from 2010 to 2020.

100 Report on environment and utilities sustainability, Worldwide brewing alliance ((2008-2009))

For both types of animal feed cascades, participants of that value chain in Brazil could earn an estimated additional profit of USD 1.90 – 2.00 per tonne of BSG on top of their margin for the beer itself.

Energy and fertiliser/compost production through anaerobic digestion. Although these applications have a lower value than animal feed, BSG is well suited to producing energy because of its relatively high carbohydrate content and high methane productivity. BSG produces 0.4 m^3 of methane per kilo of dry matter whereas cattle manure produces only 0.2 to 0.3 m^3 per kilo of dry matter. BSG also has relatively high values for NPK (nitrogen, phosphorous, and potassium) that are not altered during the anaerobic digestion process and can therefore be returned to the soil as a fertiliser. The additional profit from these applications is estimated to be USD 0.10 per tonne—this profit does not include renewable energy subsidies.[102]

How can we expand these cascades/circular solutions?

The food and beverage industry can capture the value of production losses and by-products by harnessing the power of cascades, seeking out the most valuable applications in each case. Part of the potential for cascading BSG before sending it to anaerobic digestion is already being exploited. Even though the market is fragmented and not uniformly documented, research indicates that large brewers already sell 50 – 95% of their BSG to third parties (farmers or brokers) who then use or sell it as feed for livestock. Amongst small and micro-breweries, the practice appears to be less common. Indeed, the situation is highly dependent on local factors. While Andy Wood, Chief Executive of Adnams brewery in the U.K., says that 'giving BSG to animal farms is a standard practice', Dave Johnstone, Sustainable Development Manager at SABMiller says that in some countries, although BSG is not usually wasted, often only a small share of its potential value is captured.

In some parts of the world 'an improvement of the situation would require better infrastructures' (e.g., availability of trucks, good roads) explains Gabor Garamszegi, Director of Corporate Affairs at SABMiller. But as is described below, there are a number of further generic prerequisites for a faster uptake of circular models in the food and beverage sector. Industry associations as well as government agriculture extension services and industry regulatory bodies could play an important role in creating these conditions.

- **Awareness building.** Many solutions in use today already reflect circular principles, but further awareness building would certainly enlarge the room for action. In the view of SABMiller's Dave Johnstone, while price differences across regions and seasons are massive—he cites the highest prices at 15 times the typical minimum— the price of BSG 'will go up in a sophisticated agricultural environment'. This is because, as Johnstone puts it, 'a lot of BSG value resides in the ability of brewers to understand their environment and what the real market value of BSG is'—value driven by both globally traded feed grains, energy sources and other local circumstances. In some markets (e.g., Europe, India), players already recognise BSG's value. According to Johnstone, with some knowledge of BSG value and the local dynamics, some breweries have managed to step change the value generated from these streams. Awareness building could be reinforced by landfill disincentives that discourage outright waste or, preferably, by incentives to encourage alternative uses.

- **Innovation.** Finding new technologies and applications for wastes and by-products of the food and beverage industries is a key enabler in the value capture process, as illustrated by the potential value of Professor Clark's microwave process that dramatically improves the extraction of essential oils from orange peel (see sidebar on the bio-refinery).

- **Collaboration among companies within the value chain.** New partnerships among businesses may be needed in order to manage currently wasted resources and use them in a valuable way. For example, several food and beverage production sites could form a cooperative partnership to share transport costs to bring food-based materials to farmers or, in the case of BSG, sharing the costs of a service or infrastructure to dry the grains for shipment to fish feed manufacturers. *Valorising waste usually*

101 Nutreco is a publically traded Dutch company producing fish feed for the fish farming industry. Nutreco has 100 production facilities and 8 research centres in more than 30 countries)

102 There are no subsidies for anaerobic digestion in Brazil, only the facilitation of access to credit. In other countries, such as the U.K., subsidies for anaerobic digestion can be up to USD 3.2 per hectolitre of beer produced due to the feed-in tariff on the energy produced

3. How it works up close
Continued

The bio-refinery—The workhorse of the future

In the future, food waste—especially from the supply chain—and other organic materials will be processed in a bio-refinery, a concept that is expected to be an important building block for a bio-based economy. This is especially relevant for pure waste streams that are typically found in manufacturing processes.

In many ways bio-refineries will emulate today's conventional petroleum refinery. Instead of using a fossil feedstock, a bio-refinery will process organic material, such as agricultural residue and food waste into chemicals and fuels, using a range of physical, chemical, and biological technologies. From the organic feedstock, the bio-refinery will extract high-value chemicals, such as those for cosmetics or medical purposes. A well-designed refinery will not only extract these high-value components but also fuels like ethanol and methane and a set of 'platform molecules' such as succinic acid, which can be processed further into bio-plastics and many other products.

Such full-fledged 'second-generation' bio-refineries that are able to create multiple products from a single feedstock—analogous to today's crude oil refinery—are now starting to operate at commercial scale for wood biomass—Processum in Sweden and Borregaard in Norway are examples. Similar plants for a broader set of feedstocks, including food processing waste—and in third-generation plants even multiple feedstocks— is therefore not mere 'wishful thinking'.

Orange peel illustrates how a bio-refinery can extract value from a food processing by-product. The peel contains essential oils, from which the chemical limonene can be extracted for use by the cosmetics industry as a fragrance and by the electronics industry as a degreasing solvent. After extraction of limonene, the peel waste can be fermented to generate bio-ethanol, as a new facility in Valencia, Spain, demonstrates.[104] The residue can then be pressed into citrus peel pellets and fed to animals. The high value of the essential oils as well as the high concentration of orange peel waste at juice production plants makes orange peel valorisation commercially attractive, with a current price per tonne of USD 400. We expect current processes to become more efficient, which will allow companies to profitably exploit smaller waste volumes and expand the scope of bio-refining to different types of organic waste that contain small quantities of highly valuable chemicals such as polyphenols from grapes. A recent example of such an innovation for orange peel processing is a one-step microwave treatment currently being developed by Professor James Clark and Lucie Pfalzgraff of York University's Green Chemistry Centre of Excellence in the University's Department of Chemistry (U.K.). This scalable and flexible process could be used to extract pectin and essential oil from orange peel much faster, less expensively, and without the need for additional process chemicals.

Professor Clark has established a programme to examine ways of extracting value from orange peel using safe and sustainable chemistry. Christened the Orange Peel Exploitation Company (OPEC), the project is a partnership between researchers from York, the University of Sao Paulo, Brazil and the University of Cordoba, Spain. OPEC will target products such as the widely used additive in domestic products d-limonene, pectin, and mesoporous carbons that can be used as water purifiers, as well as chemical commodities such as cymene, all of which have the advantage of being bio-derived. Professor Clark says: 'The by-product of the juicing industry has the potential to provide a range of compounds, offering a more profitable and environmentally valuable alternative to current waste use practices. We are seeking to do this by harnessing the chemical potential of food supply chain waste using green chemical technologies and use nature's own functionalities to obtain sought-after properties in everyday products.

Another large pure waste stream that could be commercially exploited is used coffee grounds. A study commissioned by Starbucks Hong Kong showed that the company could bio-refine its 5000 tonnes of coffee grounds (and uneaten pastries) every year into bio-based chemicals and intermediates, especially succinic acid, a key component of bio-plastics and a valuable platform molecule.

Further technological development is needed to allow commercial processing of cellulose-rich material. Processing technology for cellulose material would allow companies to address a much wider range of plant material such as agricultural waste. An important step to commercialisation will be the first large-scale bio-refinery constructed with the help of a EUR 199 million grant under the European Union financing mechanism NER300 by a consortium consisting of BioMCN, Siemens, Linde and Visser & Smit Hanab. This project will produce chemicals and biofuels from wood biomass via gasification to syngas.

requires entrepreneurial flexibility, as commercial opportunities often exist outside traditional core business activities. It would not necessarily be a priority for a business in the brewing industry to diversify into hydroponics.

Further opportunities for cascading food processing by-products

Like brewing, most food processing generates by-products that can have a value in other industries. We illustrate this with a few further examples. Plant-based food by-products have well-established valuable applications, such as Caudalie, a French company using grape skins as a source of phenols. Also the Guigan sugarcane company in China finding a market for all of its by-products and waste streams: bagasse into the paper industry, molasses into alcohol production, and its filter sludge as an alternative fuel into the cement industry. Animal by-products also supply ingredients to many chemical, pharmaceutical, and personal care products industries. A traditional example is the cascaded use of milk by-products to make casein glue, which was once used extensively in the woodworking industry. The latest milk-based innovation is a stunningly sleek new fibre made from milk residues and known as Qmilch®. It was put on the market in 2011 by microbiologist and fashion designer Anke Domaske. The fibre not only has a smoother surface structure than either wool or cotton, it also offers hypoallergenic, antibacterial, and moisturising properties. The fibres are created by heating casein powder derived from non-food-grade milk and liquid spun off in cheese centrifuges, i.e., from biological materials that are wholesome but would otherwise be thrown away, and refined with beeswax, but not with artificial additives such as optical brighteners.[103]

2. Clothing

Expanding the adoption of circular solutions for clothing is a significant opportunity, both to create new profitable businesses and to reduce the use of virgin materials. Clothing is a large sector characterised almost exclusively by linear consumption models that produce considerable landfill or simply leave apparel unused. At the same time, producers' profits are increasingly under pressure from volatile and rising input prices. While a few circular clothing initiatives exist, they are still small relative to the large volume that clothing represents globally.

Why is clothing waste a problem?

Clothing is a good choice to test the viability of circular business models in consumer products, as it is a large sector, measured by both expenditure and resource use. Total annual global consumption amounts to USD 1.4 trillion or an estimated 91 billion garments sold. In the U.K., consumers spend USD 63 billion (representing 5% of total consumer expenditure) on the purchase of 1.8 billion garments annually (an average of 30 garments per capita).[105]

Clothing currently accounts for a considerable amount of waste in the form of garments that are discarded at end of use:

- Across Europe and North America, huge quantities of clothing are discarded and end up in landfill. We estimate this to be 15 million tonnes annually.[106]

- Even in the U.K., where collection rates of used clothes are as high as 65%,[107] close to half a million tonnes of clothing is sent to landfill or incinerated each year.[108]

- In other countries, a higher proportion of clothing is sent to landfills—only 15% of end-of-use clothing is currently collected in the U.S.[109] and only 25% in Europe overall.[110]

Besides discarded clothing, there is an enormous amount of wastage-in-use. Consumers regularly buy clothing that they rarely use, typically because it no longer meets their needs in terms of fit, fashion, or taste.[111] WRAP estimates that U.K. consumers have around USD 50 billion worth of clothing hanging in their wardrobes that hasn't been worn for a year or more.[112]

The amount of waste globally is expected to increase not only as a function of population growth but also as incomes rise in emerging markets and the world's new consumers adopt the trend towards 'disposable clothing' or 'fast fashion'.

103 Qmilch® website, www.milkotex.com

104 'Citrofuel - Demonstration project on a new process for second-generation bio fuel production: bio ethanol from citrus flesh', European Commission article, LIFE09 ENV/ ES/000433

105 Euromonitor clothing statistics, 2012 ; Wrap, 'Valuing Our Clothes', 2012

106 Euromonitor clothing statistics, 2012; SMART association; EPA, Municipal Solid Waste Generation, Recycling, and Disposal in the United States, 2010; European Commission, Recycling Textiles Project (http://ec.europa.eu/research/growth/gcc/projects/recycling-textiles.html)

107 WRAP, 'Valuing Our Clothes', 2012

108 It is estimated that 31% of end-of-use clothing in the U.K. ends up in landfills and 7% in incineration – WRAP, 'Valuing Our Clothes, 2012

109 EPA, Municipal Solid Waste Generation, Recycling, and Disposal in the United States, 2010; SMART association

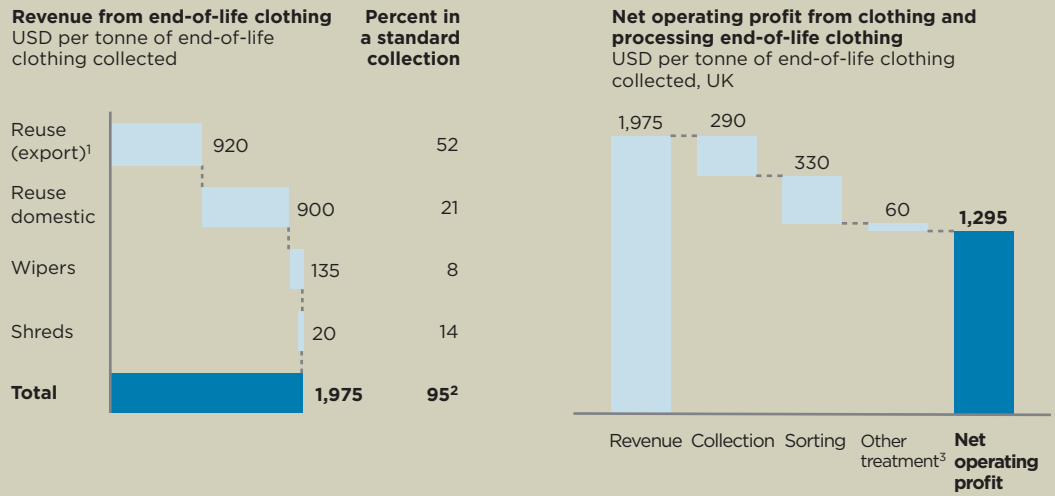
110 European Commission, Recycling Textiles Project (http://ec.europa.eu/research/growth/gcc/projects/recycling-textiles.html)

111 According to WRAP's 2012 survey as part of 'Valuing Our Clothes', 77% of adults who had not worn some of their clothes in the past year cited 'no longer suitable' including fit, style and fashion as a reason the clothing has gone unused

112 WRAP, Valuing Our Clothes, 2012

3. How it works up close
Continued

FIGURE 10 **Clothing: Current collection and sorting practices prove a profitable circular business model**



1 Includes all reuse within the system (e.g. those collected by charity shops, sold through eBay and other second hand stores, given informally to friends and relatives), not only the clothing collected by processors which is reused in the UK
2 5% of collected clothes and up in landfill
3 Includes the cost of cutting cloth into wipers but excludes shredding costs (shreds are assumed to be sold as fibre to a cutting mill). Also includes, baling cost for all material and disposing costs for material which is sent to landfill

SOURCE: WRAP 'Valuing Our Clothes' 2012, WRAP 'Textile Flow and Market Development Opportunities' 2012, Expert Interviews; Ellen MacArthur Foundation circular economy team

From a business perspective, as demand for clothing inputs rises and manufacturers push the efficiency of their linear production systems, clothing producers are increasingly vulnerable to volatile input costs. Meanwhile, average global clothing prices have decreased 2% from 2006 to 2011 from USD 15.2 per garment to 14.9.[113] Rising costs and eroding retail prices has resulted in a price-cost squeeze for manufacturers, leading to price wars among competitors and a ruinous 'race to the bottom'.

Which circular business models work best for clothing?

We believe that profitable business models that reflect circularity principles can be expanded in two main areas: 1) optimising the end-of-use flow and 2) creating radical new collaborative consumption models. These build primarily on the power of the first two circles—the inner circle, which we refer to with the shorthand 'reuse', and circling longer, which we refer to as 'recycling'. They are also complemented by the power of cascading and purity circles, as clothing that reaches its end-of-use and cannot be reused as clothing or recycled into yarn can be cascaded into other industries to be used as wipers, stuffing or insulation and, finally, to decomposition into compost for return to the soil.

Optimising the end-of-life flow for clothing

Increasing global collection rates to U.K. levels. The first step towards a circular model for clothing is to dramatically increase the collection and reuse of garments at the end of life. This clothing stream has huge potential to create economic value, for manufacturers, retailers, and consumers. We have explored multiple ways to extract value from clothing that is currently thrown away, in direct reuse of clothing; in mechanical and chemical reprocessing to create new textiles without using virgin materials; and re-purposing clothing to make secondary products such as cleaning cloths (rags and wipers) and insulation.

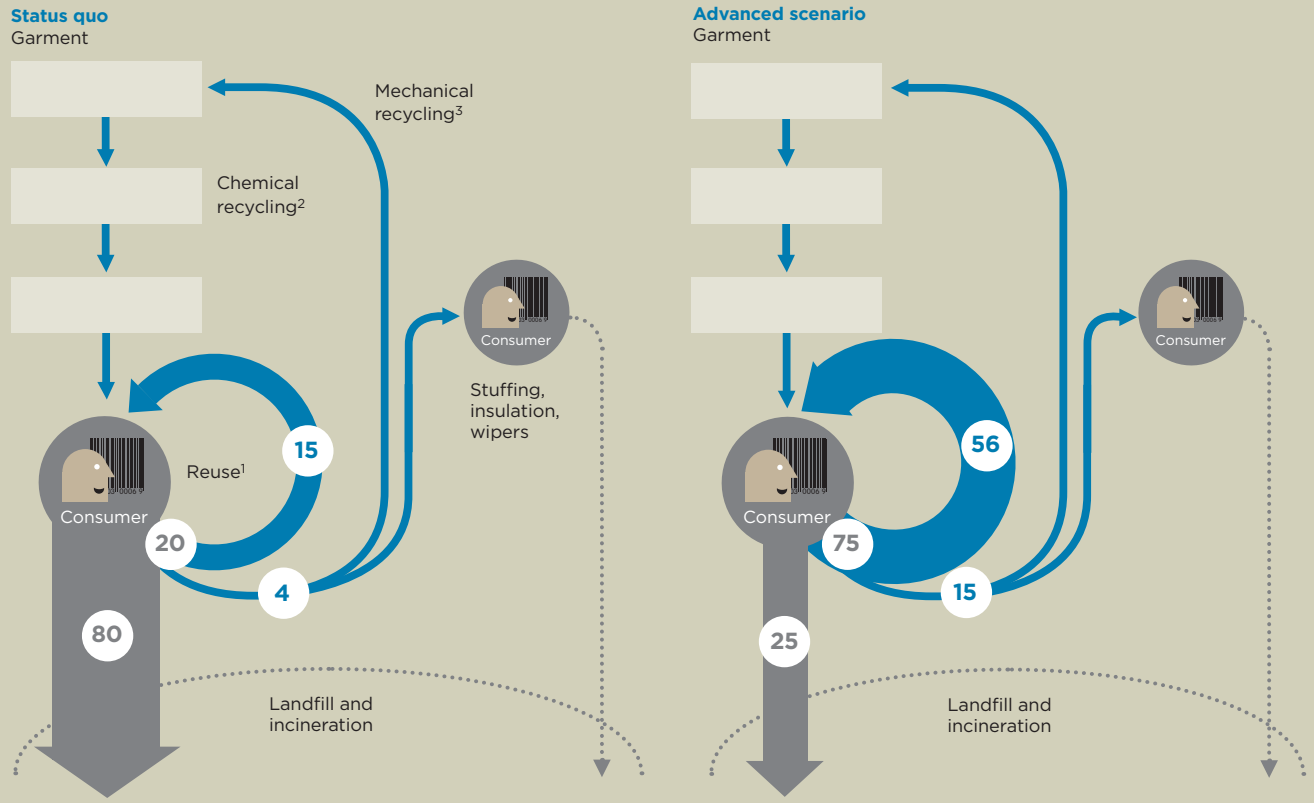
When a tonne of textiles is collected in the U.K., it is used for four main applications: U.K. reuse (21%), export reuse (52%), cleaning rags or wipers (8%), and shreds (14%).[114] Shreds is a clothing industry

113 Euromonitor clothing statistics, 2012

114 WRAP, Valuing Our Clothes, 2012; WRAP, Textile Flows and Market Development Opportunities in the U.K., 2012; Expert interviews

FIGURE 11 **Clothing: Further increasing circularity through greater collection and closed-loop recycling, both mechanical and chemical**

End-of-life material flows for Europe and North America Percentage of total end-of-life clothing weight



Note: All fibres treated as technical materials since most dyes and coatings used today mean that even natural fibres cannot be returned to the soil
1 Includes both domestic reuse within the UK and reuse exported abroad
2 Describes process to depolymerise and repolymerise fibres to create new fibres of similar quality to virgin production. Minimal chemical recycling currently of polyester (Teijin) in Japan and nylon (e.g., Aquafil)
3 Describes process to shred and card fibres, then make new yarns and clothing (e.g., Marks & Spencer 'shwopped coat')

SOURCE: WRAP 'Valuing our clothes' 2012; WRAP 'Textile Flow and Market Development Opportunities 2012, Ellen MacArthur Foundation circular economy team

term for unravelled or chopped textiles, which are then used to create new yarn through mechanical recycling, stuffing for furniture and mattresses, and as insulation in homes and cars. These flows represent the destinations of all clothing which reaches the end of its use with a consumer in the U.K., including items collected through charity shops, textile banks, resold online, informally traded amongst friends or relatives.

If sold at current prices across the four usage streams, a tonne of collected and sorted clothing can generate revenues of close to USD 2,000. After subtraction of the costs of commercial collection and sorting of USD 680, the profit potential is around USD 1, 300 per tonne[115,116] (Figure 10).

The potential revenue pool in the U.K. with a current collection rate of 65% is USD 1.4 billion. Making such reuse and reprocessing a mainstream part of the clothing value chain translates into less expensive material inputs for retailers and manufacturers, and (assuming that competition will result in a certain pass-through of the savings to shoppers) less expensive clothing for consumers.

U.K collection rates are relatively high compared to the rest of Europe and North America, and the first step should be to dramatically increase the collection and reuse of clothing across those regions. Lifting collection rates in North America and Europe to same level as in the U.K. would generate a total of 14 million tonnes of end-of-use clothing annually or a global profit pool of USD 26 billion. It must be noted that the acquisition cost for textiles is often zero as people donate clothes. However, this could change in the future as we have seen in other industries where end-of-life products become valuable as more options emerge to re-apply them (Figure 11).

Critically, this shift will also dramatically reduce the use of virgin material in the clothing industry as well as the cascaded-use industries, thereby relieving pressure on agricultural inputs, such as cotton, and fossilised carbon inputs, such as petroleum, which is a key input for polyester. A collection rate of 65% in the U.K. currently generates USD 3 billion in material savings annually. Moving collection rates in Europe and North America to match the U.K. at 65% adds up to

115 WRAP, Valuing Our Clothes, 2012; WRAP, Textile Flows and Market Development Opportunities in the U.K., 2012; Expert interviews

116 Operating profit does not include capital costs and only the variable costs associated with collecting, sorting and cutting textiles

3. How it works up close
Continued

USD 35 billion in material savings or nearly 61% of the current material costs associated with European and North American clothing consumption. Globally, the material savings could total USD 71 billion.[117]

High collection rates are only economical if each collection includes a sufficient quantity of directly reusable clothing; this is the stream that commands a higher price and drives the profit of the industry. For example, clothing for export commands a price of USD 1,700 per tonne, whereas the price for shreds is USD 140 per tonne. Against a collection and sorting price of USD 600, it is uneconomical to collect and sort clothing if the only output is of 'shred quality'. Therefore, to achieve these high collection rates and corresponding projected value, it is critical that the 'cream' or highest-value end-of-use clothing is not skimmed away from the rest. Collections that encourage consumers to only give 'like-new' items and discourage any items that show signs of wear diminish the industry's ability to process the full volume of end-of-use clothing economically.

MYTH
Only 'gently worn' or like-new clothing is useful to donate; the rest is rubbish

Reality: Most used textiles still have value.

In fact, of all the used clothing that is actually collected, only 5% ends up in landfill.[118] Used textiles that are not reused domestically, or exported for reuse in emerging markets, are cut into wiper cloths for industrial cleaning or shredded for further use as furniture stuffing, mattress stuffing, and car insulation. Scraps can even be recycled into new yarns to make new clothing.

Going further—Circularity by intention
It is interesting to look at what can be done with existing textile material flows to improve their circularity—it is perhaps more interesting still to begin to look at the opportunities posed by designing materials and products intentionally for a circular economy. If we know that we would ultimately like to have a regenerative textiles economy then how might we re-think product design to enable this?

An example of this is new chemical recycling technologies that offer the promise of closing the loop on recycling systems. Unlike mechanical recycling, chemical recycling maintains fibre quality throughout the recycling process, which means that the waste from one T-shirt can be used to make a new T-shirt of the same quality. In a scenario that increases world-wide collection rates to 75%, or slightly more than current paper recycling rates,[119] and 9% of the textiles collected is processed through chemical recycling, material cost savings increase from USD 35 billion to USD 41 billion for North American and European clothing consumption.

Chemical recycling is still advancing, but is already a reality today. One example is the Common Threads clothing initiative started by **Patagonia**, a California-based outdoor clothing company. As one part of the initiative, it recycles polyester clothing chemically in partnership with Teijin in Japan. The material originates and is returned to Japan where it is re-made into new fibres for new Patagonia garments. As Rick Ridgeway, VP Environment Initiatives at Patagonia, explains: 'clothes go in and clothes go out'. The chemical recycling step is only taken after the garments have cycled through re-use and have no remaining useful life as clothing. **Aquafil**, based in Trento, Italy, and a recognized leader in nylon research and production, has developed a process to chemically recycle nylon that achieves the same quality of fibre as through virgin production. According to CEO Giulio Bonazzi, the process reduces the environmental impact of nylon production by 50 – 80% compared with virgin production and is economically competitive.

117 Collection rates outside of Europe and North America are assumed to be at U.K. rates already based on anecdotal evidence – Expert interviews

118 SMART Association

119 Current rate of paper recycling in the U.S. is 72% - EPA, Municipal Solid Waste Generation, Recycling, and Disposal in the United States, 2010

In a recent development, **Worn Again**, a zero-waste textile company based in the U.K., has started using a process to separate cotton from polyester and recycle the fibres into cellulose to be used in viscose (a natural fibre) and polyester. Only 0.1% of the fibre is lost in the process and there is no shortening of fibre lengths or reduction in quality, typical drawbacks of mechanical fibre recycling. In addition, tests to date indicate that this process can return polyester to use not only 'economically' but at the price of conventional polyester, i.e., competitively.

MYTH
Natural fibres like cotton are the most environmentally friendly choice and oil-based synthetics, for example polyester, should be avoided

Reality: Natural fibres can have a worse impact on the environment than synthetic blends.

According to analysis by WRAP, a tonne of cotton has a footprint of 28 tonnes of CO_2e and 3,100m^3 of water. Polyester's footprint is 21 tonnes of CO_2e and 80m^3 of water. Plus, polyester can potentially be chemically recycled to produce fibres of virgin production quality, cycling indefinitely. In contrast, natural fibres are currently mechanically recycled, which results in a shorter, lower-quality fibre that can only cycle a few times before the quality deteriorates too much for further use in making fabric.

Regeneration of soils in end-of-life clothing optimisation

The circular economy creates value through defined, separate, technical and biological material flows. In this way, the nutrients embodied in biological materials can be returned to the food and farming systems to regenerate the soil at the end of a cascade. An example is PUMA's InCycle™: a new line of biodegradable or recyclable shoes, clothes and apparel, all Cradle-to-Cradle™ certified. Companies that design fabrics for biodegradability must design each chemical treatment stage (e.g., dyes and finishes) to ensure that the chemicals degrade and do not persist in the soil. When PUMA took on the challenge of designing for full recyclablility and biodegradability, it required changes to materials, pigments, and manufacturing.

Another example is provided by Switzerland-based Rohner—maker of 'Climatex Lifecycle', a synthetic fabric 'safe enough to eat'—who describes the arduous and instructive process of developing the fabric on its website. Most suppliers were reluctant to reveal the ingredients in their dyeing and finishing processes, and Rohner had to winnow down the list of possible dyes from 4,500 to just 16 that were appropriate for the fibres.

In addition to innovation in dyes, the goal of biodegradability will also require innovation in finishes such as fire retardants added to cascade products (stuffing and insulation) and some clothing to ensure that the fibres can return to the earth, replenishing the soil without contamination.

An important source of economic value in the clothing reuse model comes from the durability and reuse of garments, which often depends on blended fibres. Given this value, the critical activity is to collect as much textile material as possible and extend its useful life in the tightest circle possible—through reuse and then cascade.

In future, it may be possible to achieve the ideal of keeping biological and technical materials separated, either by making fibres equally durable using biodegradable materials or by developing technologies that allow the fibres to be separated at their end-of-life (Figure 12).

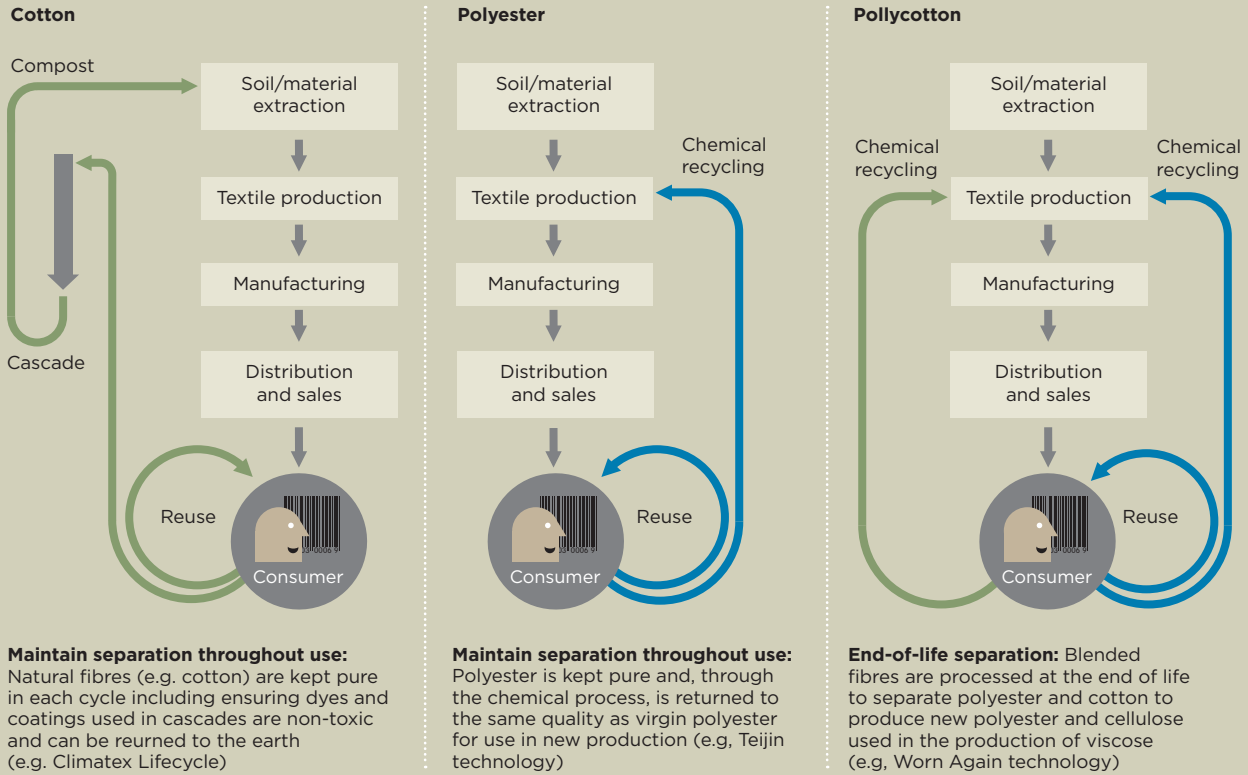
In addition, an analysis of the nutrient value of cotton shows that the majority of nutrients are held in the cotton plant rather than the buds used to make fibres. Recovering nutrients in cotton lint either from textile waste water or end-of-use textiles yields only 0.1 million tonnes of N, P, K, which is less than 0.5% of current consumption of chemical fertilizer.

Patagonia's Common Threads initiative takes a similar tack. The initiative currently focuses on the hierarchy stages reduce, repair, reuse

3. How it works up close
Continued

FIGURE 12 **Clothing: In the ideal state, biological and technical materials should be kept separate or separated at end of life using new technologies**

End-of-life material pathways for biological and technical products



Maintain separation throughout use: Natural fibres (e.g. cotton) are kept pure in each cycle including ensuring dyes and coatings used in cascades are non-toxic and can be reurned to the earth (e.g. Climatex Lifecycle)

Maintain separation throughout use: Polyester is kept pure and, through the chemical process, is returned to the same quality as virgin polyester for use in new production (e.g, Teijin technology)

End-of-life separation: Blended fibres are processed at the end of life to separate polyester and cotton to produce new polyester and cellulose used in the production of viscose (e.g, Worn Again technology)

SOURCE: Ellen MacArthur Foundation circular economy team

and recycle. Biodegradability is not included to make sure that products can be used in their original form as long as possible. Nellie Cohen of Common Threads at Patagonia explains: 'If you own one jacket that lasts, that's better than three that don't. I think we'd have concerns about the potential sacrifices in quality in designing for biodegradability'.

Radically new models for collaborative consumption.

In addition to greater collection, we have also explored new models that aim to productively utilise the in-use surplus lurking in many wardrobes in what investment analyst Mary Meeker calls an 'asset-heavy world'.[120] This idea has already reached clothing and can be extended with a radical new business model to offer everyday clothing for hire , allowing consumers to easily 'swap' clothing whenever they desire variety, need a different size, wear out a garment, or for any other reason that previously would have led to clothing being discarded or left unworn at home. The rent-a-garment approach not only has potential to be a profitable business, it also offers more benefits to a certain segment of consumers by giving them access to a much wider range of clothing and the ability to eradicate their 'mistaken' choices quickly and conveniently. While this example might seem very innovative, it serves as stimulus to think creatively. Consumer research would of course be needed to better understand consumers' acceptance.

Precedents for everyday clothing-for-hire. A wide-scale rental model for clothing builds on current market trends towards 'collaborative' living and consumer insights:

• Rental models in general are clearly on the rise. Perhaps the best-known example today is Zipcar in North America, which gives users access to short-term hourly car rentals. Zipcar membership grew from 200,000 to 500,000 in only three months in 2011, and is expected to increase to 2 million by 2020.[121]

• Formal wear rentals, particularly men's wedding attire, have a long history and have been joined by other new-clothing rental models, mainly for one-off hire and expensive items. In the U.K., 'Girl Meets Dress' provides one-off rental of formal wear and clothing for socialising; one counterpart in the U.S. is 'Rent the Runway', which offers designer-label garments. For handbags, there is 'Fashion Hire' in the U.K. and 'Bag, Borrow or Steal' in the U.S. The basic business model is also well established for other infrequently used items: ski hire has always been available at the slopes, skates at the ice or roller rink, bowling and golf shoes, and so on. Unsurprisingly, rental models for maternity wear have also joined this line-up, e.g., 'Love Your Bump'.

New models are emerging online that demonstrate the lack of apparent stigma and willingness to exchange used clothing, much as many consumers have done informally amongst friends and family. One example is ASOS Marketplace, an extension of the new-clothing lines of U.K.-based retail and 'fashion destination' ASOS. The Marketplace operates internationally and provides a channel for consumers to resell their used clothing as well as for small new fashion businesses to reach ASOS's large consumer audience.[122]

Other established sites selling used everyday and dress-up clothing are mainly focused on the U.S. and include Twice, Poshmark, Threadflip (planning to expand to international sales), which target mainly women's clothing, and ThredUP, which target mainly children's clothing.

Online retail has increased rapidly across multiple categories, accompanied by huge investments in front-end systems and logistics. It is now easy for consumers to review and choose the right products, and for products to be delivered to their homes, nearby stores or other collection/drop-off locations—and in some cases— the handling of returns. These service enhancements are rapidly changing the entire retail landscape in developed markets.

120 Mary Meeker, 2012 Internet Trends (Update), 2012

121 Forbes, Zipcar Revs Up Membership Growth, Stock Cruising to $27, 2011

122 According to ASOS, 80% of sellers are individuals using the site as a way to monetise their wardrobes, while 20% are vintage or new fashion businesses. Source: econsultancy.com (http://econsultancy.com/uk/blog/8558-asos-rketplace-sales-grow-690-over-the-past-year#)

3. How it works up close
Continued

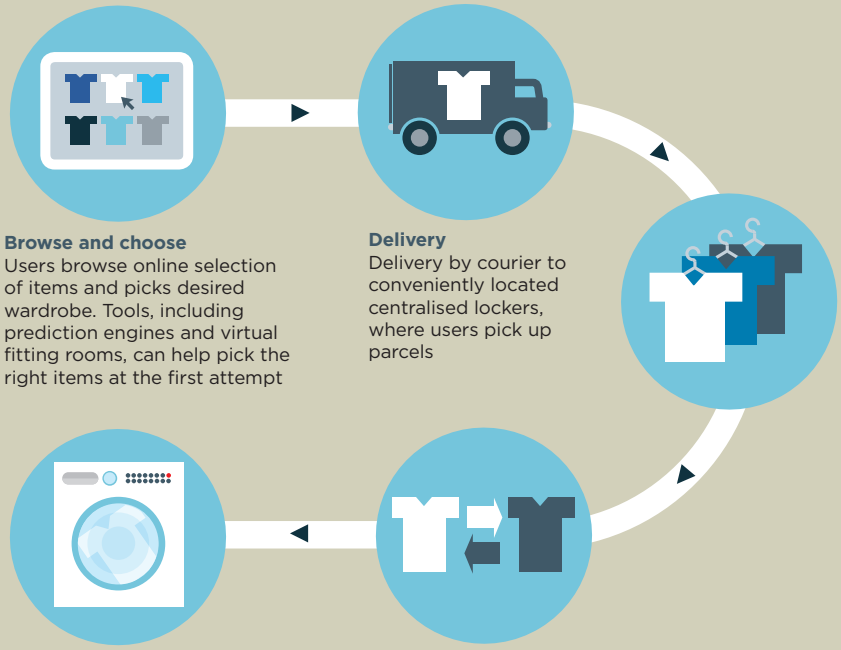
A 'Netflix for clothing'

To test the potential of a different approach, we have envisioned one version of wide-scale rental: a 'Netflix for clothing' (Figure 13). Netflix charges a monthly fee for unlimited access to a selection of television programming and cinematic films. For an analogous clothing rental service, consumers pay a membership fee equivalent to their current annual spend on clothing (~USD 1,000 per year for the U.K.). In return, they receive access to a full week's wardrobe with the possibility to swap items on a weekly basis. Such a model reduces the amount of unworn and unwanted clothing in our wardrobes, as items that would have otherwise remained unworn are currently being worn by someone else. This model also delivers a better solution for consumers by increasing the range of clothes available through the year and providing regular laundry service.

In envisioning and analysing this model, we chose the U.K. as the initial geography; however, the model is easily transferable to other countries. For the moment, it is most relevant in North America and Europe given the high penetration of online retail in these regions. However, there are examples of clothing-for-hire services in Asian economies, such as 'Open Closet' in South Korea, which has begun to take in business suit donations and offer them to young job seekers on a rental basis.

FIGURE 13 **Clothing: New 'Netflix for clothes' is an example model that delivers more choice and more style for consumers by providing 'fast fashion' shared amongst a community of users**

Illustration of clothing rental model



Browse and choose
Users browse online selection of items and picks desired wardrobe. Tools, including prediction engines and virtual fitting rooms, can help pick the right items at the first attempt

Delivery
Delivery by courier to conveniently located centralised lockers, where users pick up parcels

Streamlined wardrobe
At any given time, users have 18 items of clothing hanging in their wardrobe

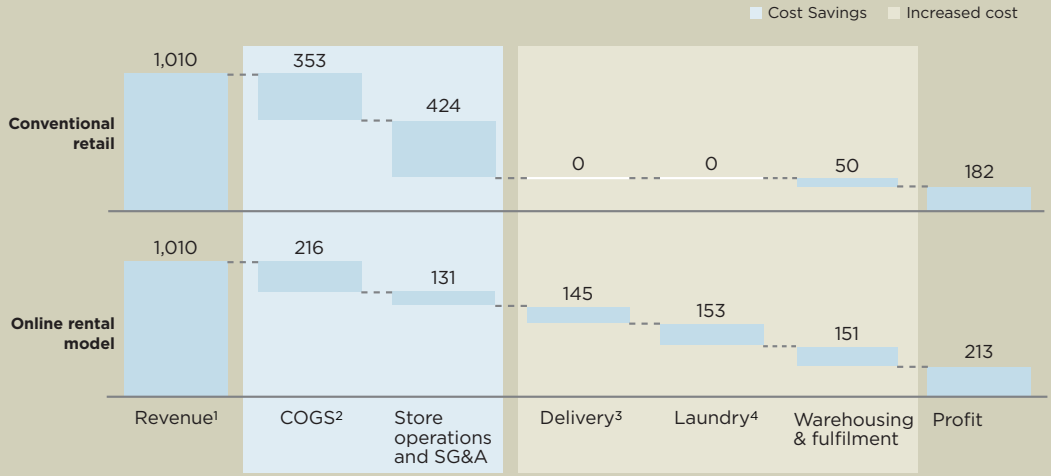
Returns
When the user tires of the style, repair is needed or a new size required, items are packaged and brought back to the centralised lockers for pick up. Users can swap as many items as necessary

Wash & care
Clothing is returned to the central depot where it is washed, inspected, and readied for the next user

SOURCE: Ellen MacArthur Foundation circular economy team

FIGURE 14 **Clothing: Online rental archives cost savings in COGS and delivery partially offset by increased cleaning costs**

Comparison of online retail and online rental profit USD operating profit per rental customer



1 Revenue assumed to be the same in the retail and rental scenario (i.e., consumers spend the same amount of money to gain access to clothing through rental as they would to buy new pieces of clothing each year)
2 Savings on cost of goods sold (COGS) driven by decrease in clothing production from 29 garments/year under an ownership model to 16 garments/year for rental
3 Small delivery cost compared to current online retail model from moving to a centralised 'locker' delivery system (similar to Deutsche Post's packstation system)
4 Rental clothing is washed after each return by the consumer

SOURCE: Euromonitor, Expert interviews, WRAP 'Valuing Our Clothes' 2012, Ellen MacArthur Foundation circular economy team

What could the profit potential look like?

This model presents a real economic opportunity of ~USD 200 in operating profit per renter[123] and is sensitive to the assumptions for delivery costs, laundry, and the average service life of the garments[124] (Figure 14).

In addition, it results in 14 fewer garments being produced and reaching their end-of-use annually per renter. If we assume 6 million subscribers in the U.K. (approximately equivalent to the share of the U.S. population that subscribes to Netflix),[125] this adds up to a material savings of USD 236 million. Considering the full system, a scenario that includes rental and achieves 75% collection of all end-of-use clothing results in a material savings of USD 3.8 billion for the U.K. Projected to North America and Europe, the savings rise to USD 44 billion.

In the rental model, the total amount of laundry increases as more cleaning is required between uses; however, the overall effect of reduced production, increased laundry, and increased transport is a net water savings (37 m^3 per renter annually), net material savings (USD 38 per renter annually), and a small net carbon savings (11 kg CO_2e per renter annually).

In addition, the model may be expected to yield greater benefits in the future as rental providers have an incentive to increase the durability of their clothing inventories and reduce the energy requirements for laundry. In moving towards this kind of collaborative consumption model, we would shift from a situation in which each individual or household has a small incentive to buy durable clothing (either to be able to wear the clothing longer or to be re-sell it at a higher price reflecting its residual value) to one in which one or several companies have a large incentive to increase durability as a critical driver of business profitability. In a similar vein, WRAP reports that U.K. households that change their laundry habits towards lower energy intensity (washing less often, washing at lower temperatures, reducing the use of tumble dryers, and washing with fuller loads) could save USD 16 per year. By contrast, with 6 million renters, clothing rental companies would be looking at a savings 'pie' worth approximately USD 100 million a year.

For clothing, the potential impact of switching from the individual linear consumption model to a circular wardrobe rental business is already visible today. Elis, a USD 1.3 billion European company that rents industrial clothing and textiles (uniforms, safety garments, table linens, bed linens, etc.) and serves 290,000 customers, are continually working to increase the durability of their offering, which has benefits for both their consumers and their business.

123
1 Revenue assumed to be the same in the retail and rental scenario (i.e., consumers spend the same amount of money to gain access to clothing through rental as they would to buy new pieces of clothing each year)

2 COGS savings driven by a decrease in the production of clothing from 29 garments/year under an ownership model to 16 garments/year for rental

3 Small delivery cost compared to current online retail model from moving to a centralised 'locker' delivery system (similar to Deutsche Post's packstation system).

4 Rental clothing is washed every time the consumer returns an item

124 Delivery cost for an 11kg box to a centralised locker is assumed to be USD 8 compared USD 16 for at home delivery comparable to timed grocery drop-offs. Average service life of clothing is assumed to be 75 washes. Using less intensive laundry practices, laundry costs are reduced to USD 0.07 per item

125 Associated Press, By the Numbers: Netflix Subscribers, 2012

3. How it works up close
Continued

MYTH
Consumers' desire for fast-changing designs and a variety of styles will always have a negative resource impact

Reality: Not necessarily. Not with 'clothing for hire'

The best way to improve the resource impact of clothes is to make sure that each item is durable and used until it's really at its end-of-life— not just when it goes out of fashion. More collaborative consumption models can deliver this durability and intensity of use while also giving consumers a wide choice of styles and sizes to wear.

In a clothing hire scheme, instead of each consumer's only small incentive to buy more durable clothing (either to wear longer or to resell for a slightly higher price because of its residual value), one or more companies have a large incentive to ensure durability as a key driver of profitability. In addition, clothing is used more intensely. The dress that was previously worn only once or twice now 'goes out' several nights a month—with a new wearer. Instead of one wardrobe full of mostly unused clothes, each user has access to multiple apparel collections, and can change and update clothes more often.

How can clothing reuse be increased?

The changes needed to make a successful shift from today's linear consumption model to a fully circular system include awareness raising, scale-up infrastructure and design innovations.

Awareness building. Like the idea of the circular economy as a whole, it should be possible to accelerate business building in both areas through extensive and targeted awareness building of the value that can be extracted.

• The more radical-sounding 'year-round wardrobe hire service' has the potential to take off faster with the spread of an asset-light lifestyle among young people. Both one-off rental of women's formal wear and second-hand or 'vintage' retail options are already increasing and converging around solutions similar to conventional retail, which consumers are familiar with, including greater curation of stock and easy returns. The best-known forerunners are at the high-end of the market—'rent-a-tux' for men and formal-wear and designer labels for women. All of the elements of the business system are familiar and mature: online retail, delivery and return services, and professional dry cleaning and laundering. This promising basis might be combined with the know-how on tap at print fashion magazines or cosmetic companies as well as apparel makers or department-store chains, e.g., online 'personal shopper' services and wardrobe sets cued to colour palettes, the dress codes of different professions, and other needs, and supported by three-month trial offers and messages emphasising the wealth of choices; degree of certainty/easy 'corrections'; time, space, and money savings; and all-round convenience.

• For optimising the end-of-life flows in countries such as the U.K., much of the behind-the-scenes infrastructure is already in place for the four types of reuse of used clothing. Thus, the critical change here is to increase collection rates (see below). Awareness-building efforts here refer to helping consumers appreciate that their used clothes actually have value as well as making them aware of collection points and other opportunities to donate. Surprisingly, many people are still unaware of the value of used clothes. In WRAP's 2012 survey of U.K. consumers, the group of respondents who sometimes get rid of clothing by discarding it mixed in with other household waste were asked to explain the choice. One of the main reasons, reported by 75%, was the belief that 'the item could never be used again for any purpose'. In addition, 26% mentioned that 'the items have no monetary value'.[126]

Increasing collection. The availability and convenience of collection points also contribute to awareness building, and both should help to boost collection rates.

• *At stores.* Current campaigns by retailers as diverse as Marks & Spencer, Uniqlo, Puma,

126 *WRAP, 'Valuing Our Clothes', 2012*

'Ultimately, a closed loop approach to the reuse of not just textiles, but all types of resources, is basic common sense'.
CYNDI RHOADES (CEO, WORN AGAIN), NICK RYAN

H&M, and Patagonia to increase in-store collections are one very important step and help make donations 'cool' and at the same time routine, a regular part of weekly errands. Noting the successful mindset change in the U.K. over the previous decade regarding plastic and glass bottle returns, Cyndi Rhoades, CEO of Worn Again, says: 'People know that plastic and glass can be reused again. That's why it's quite exciting that big retailers are moving in the direction of closed loop and starting to educate their consumers on that.'

• *Via municipal waste collection.* Clothing stores are one obvious new place to locate the start of the reverse cycle for clothing. Another is the municipal waste collection process itself. In many locations, the municipal government provides space for a private textile collection company to set up its collection bins, thereby creating a new revenue stream for the municipality. In a further development, LMB and WRAP are currently trialling a 'survival bag' solution that would allow the collection of clothing alongside but—importantly—separated from household trash, keeping the clothing undamaged while greatly increasing convenience for consumers. Ross Barry, LMB CEO in the third generation of the family's '360-degree recycling' business, is optimistic about the results of the trials: 'The survival bag is so convenient for people. People don't see that there's a recycling option so they're just throwing clothing in the bin. With the survival bag, we could collect clothing along with regular household waste. The bag then just needs to be pulled off the belt in the sorting process'.

• *In other retail or recycling settings.* Other new collection systems are appearing as well, such as i:co, which installs collection boxes in retail shops. Consumers add their items to the box, which then weighs the donation and rewards the giver with an in-store voucher/coupon, the value of which reflects the weight of the items.

More collection is urgently required, however—particularly in other countries. While the average collection rate in the U.K. is already 65%, the average across the EU is only 25%, and for the U.S. only 15%. Alan Wheeler of the Textile Recycling Association ascribes part of the U.K.'s higher collection rate to the presence and efforts of the U.K.'s 6,000+ charity shops, and offers this opinion: 'I think in the U.K., there is a greater culture of charity shops, which likely leads to higher collection rates. There is more of a "waste not, want not" culture'. In other countries, the model may be more focused around in-store or municipal collections but it is critical to make these collections more accessible and part of common practice.

Design for end-of-life re-use. As a key element in the circular economy, greater consideration of end-of-life processing is needed in the design phase of clothing production (e.g., ease of repair, sorting, disassembling, and recycling). At Patagonia, for example, all clothing is designed both to be recycled and with durability in mind.

Further innovation. In addition, new recycling technologies (chemical recycling) are required in closing the loop (with separate reverse streams for biological and technical fabrics). As we have mentioned, textile innovators such as Worn Againare developing processes to recapture polyester and cellulose from cotton which can be reintroduced into the polyester and viscose supply chains. It is expected that up to 99.9% of the polyester and available cellulose will be recaptured and returned as resources into these supply chains.

3. Packaging

An integral part of most consumer goods, packaging is typically a technical component that is discarded at the time of consumption. It plays a major functional role in protecting and dispensing the product, representing a significant proportion—usually 10 – 25%—of the total product costs.[127] Packaging is also used as a vehicle for communicating differentiation and brand benefits to consumers at the shelf and in use.

Why does packaging waste matter?

Packaging represents a large proportion of consumers' use of materials and accounts for nearly 20% of household waste.[128] The frequency of purchases and high volumes associated with consumer products mean that consumers buy large amounts of packaging—an estimated 207 million tonnes globally[129]

127 Analyst reports, McKinsey Purchasing and Supply Management practice

128 Packaging in Perspective, Advisory Committee on Packaging, 2008

129 US EPA 2010, Euromonitor 2012

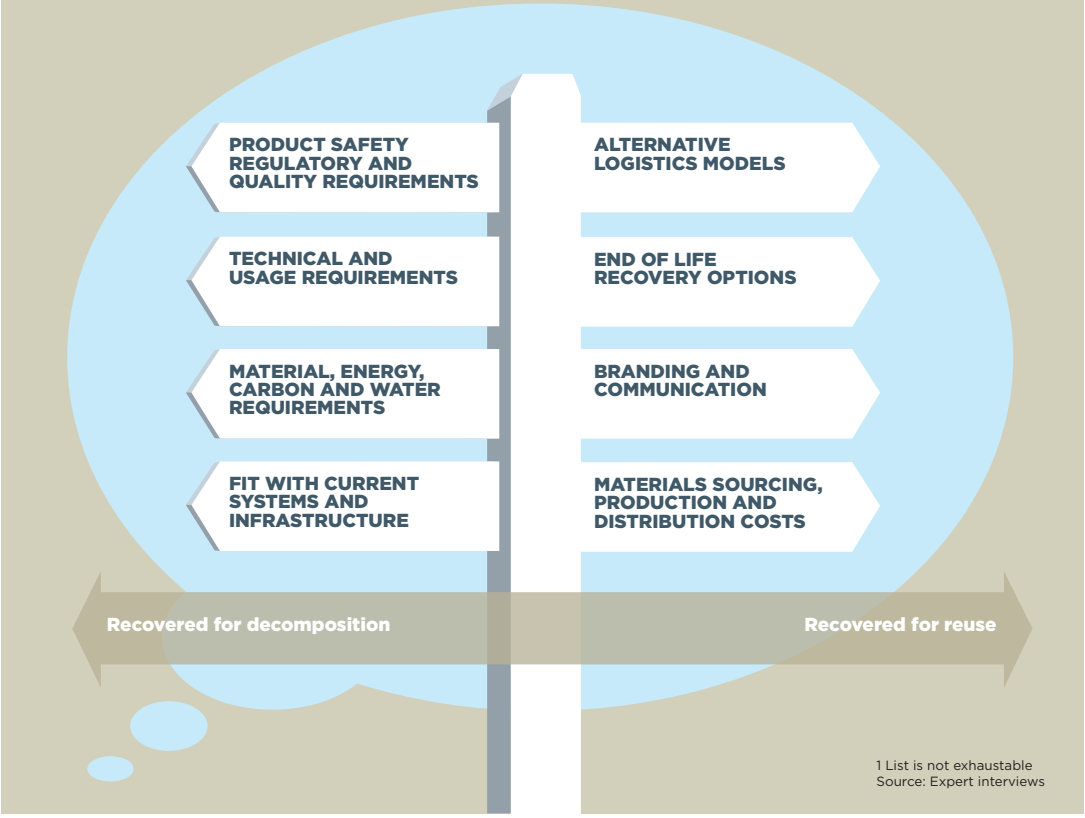
3. How it works up close
Continued

with a value of USD 384 billion each year. Although certain packaging types in some markets have moderate levels of recycling (notably aluminium cans and glass bottles in Europe), a large proportion still ends up in landfill—around 50% in the U.S., for example.[130]

Packaging is often made of materials that are combined in a way that constrain recycling or prevent the restoration of biological nutrients to the soil. Superior packaging performance, especially for films and foils, is frequently obtained by combining different types of materials. Since these materials are often chemically bonded they render recycling impossible or at best economically unattractive.

A key factor in unlocking the commercial opportunities of the circular economy is to design with the intention of creating distinct material flows. When biological materials are combined with technical ones, this can create a particularly complex challenge if resource value is to be retained. The effect of this 'hybrid' waste product is to constrain or prevent the biological nutrients from undergoing regenerative decomposition in landfills and complicate the harvesting of technical materials like polymers and metals. One example is non-degradable food packaging. The 'clamshell' packaging used for fast foods traps the food's biological materials within the non-degradable technical packaging material. Clearly, designing packaging from the outset for reverse circles requires close attention to multiple factors (Figure 15).

FIGURE 15 **Packaging: There are many considerations when determining whether a product should be designed for reuse or decomposition**[1]



1 List is not exhaustable
Source: Expert interviews

130 USA EPA 2010

Building more circular business models in packaging

Shifting the consumer goods packaging industry to circular models will result in significant material savings and reduce pollution, and represents a positive economic opportunity for manufacturers, retailers, consumers, and municipal authorities.

There are three key circular levers for fast-moving consumer goods packaging that will help close the loop:

• **Improving the 'BAU' situation:** Recycling—recycling provides an intermediate solution 'for a business as usual' situation where reuse infrastructure is not feasible. Although significant material savings can be made by collecting and recycling used packaging, a short lifecycle ensures that losses rapidly compound even at high collection rates

• **Designing for circularity – by intention:**
– Biodegradable packaging—packaging is designed for biological regeneration. Single-use packaging facilitates the return of bio-based materials to regenerate food/farming systems, or where collection systems are not established.

– Technical/durable packaging—packaging is designed by intention to facilitate reuse with existing labour, energy and resource input. Infrastructure exists to harvest materials for the next cycle.

A virtuous cycle

Recycling packaging has economic benefits for both the recycler who gains a new revenue stream and for the packaging manufacturer who gets access to (generally) lower raw material prices than for virgin stock. As part of the transition to fully circular solutions, better design and more extensive collection, sorting and recycling can deliver significant material savings.

What is the recycling profit potential?

Recycling is profitable on a global scale. In OECD countries, there is already an economic case to increase the volume and number of different materials that are recycled. This is true for the various forms of ownership of the collection and recycling services, many of which are run by a municipal authority as well as some run by the private sector. For example, DS Smith Recycling, a private company working with many public and private sector customers—and the largest paper and cardboard recycler in Europe—has delivered steady revenue and profit growth across its operations. While current technological challenges often limit post-consumer recycled material content in packaging, the lower prices of recycled materials encourage manufacturers to maximise their use.

Some consumer goods manufacturers have also made their use of recycled materials a feature of their brands. Recent research suggests 75% consumers said they are willing to pay a 5 – 10% premium for green packaging.[131] However, it is unclear whether actual purchasing behaviour will always match stated intentions.

What opportunities exist to quickly scale up recycling?

Steps required to increase recycling and quickly capture more value include improving sorting technology and, importantly, designing packaging to be conducive to circular/reverse processing. Some examples include:

For waste management companies:
Straightforward investments in existing, mature technology to separate current plastic packaging into more distinct fractions will result in large material savings. For example, by using near-infrared sorting equipment, some material recovery facilities (MRFs) in the U.S. are able to sort out the five main plastics, PET, PP, PS, HDPE and LDPE. Our analysis shows that a full scale-up to all MRFs in the U.S. would deliver an estimated annual materials saving of USD 7.3 billion and a profit of USD 2.4 billion—approximately USD 200 per tonne of plastic collected—even after taking into account capital investment required for new sorting equipment (Figure 16).[132]

131 The growing demand for green, McKinsey Quarterly, April 2012

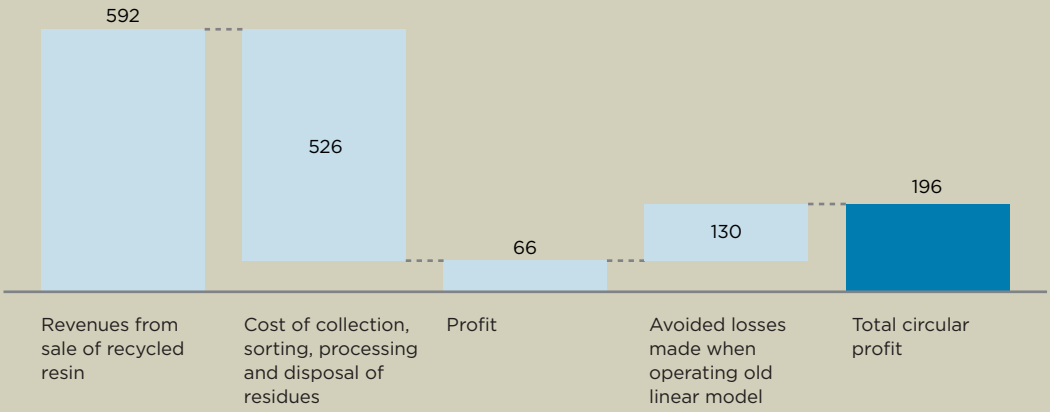
132 The Ellen MacArthur Foundation circular economy team analysis

3. How it works up close
Continued

FIGURE 16 **Packaging: Moving to better sorting of all plastic packaging collected in the U.S. generates a profit of USD 200 per tonne[1], approximately USD 2.4 bn each year**

U.S. ONLY

Profit from 'going circular'
USD per tonne[1]



1 Per tonne of plastics packaging in municipal solid waste
SOURCE: Ellen MacArthur Foundation circular economy team

For consumer goods companies:

• Designing out contaminants (e.g., colorants, plasticisers, stabilisers). Procter & Gamble developed a significantly more circular package for their latest razor. In addition to featuring lighter materials with better end-of-life options, the new packaging is also 100% free of polyvinyl chloride (PVC).[133] As April Crow, Global Director of Sustainable Packaging at The Coca Cola Company points out, "We [as a consumer goods community] need to make sure that more of the materials we put on to the market have value to encourage the circular economy approach; too many today are difficult to recycle or contaminate existing recycling streams. When we introduced the first PET bottle into the market in the late 1970s we made a commitment to develop the technology that would allow that material to go back into our packages as a secondary raw material. We supported the development of the technology and end markets to enable this." Coca Cola has a design approach that insists that their packaging must be designed to be recyclable, but also recognise there is still a role to play in increasing collection and recycling of the packaging material that they produce.

• Designing packaging for more effective sorting. Simple steps can be taken immediately in design, such as not using black-coloured materials as they cannot be detected by near-infrared equipment, or by avoiding large labels on packaging as the label can be mis-detected as the actual packaging material.

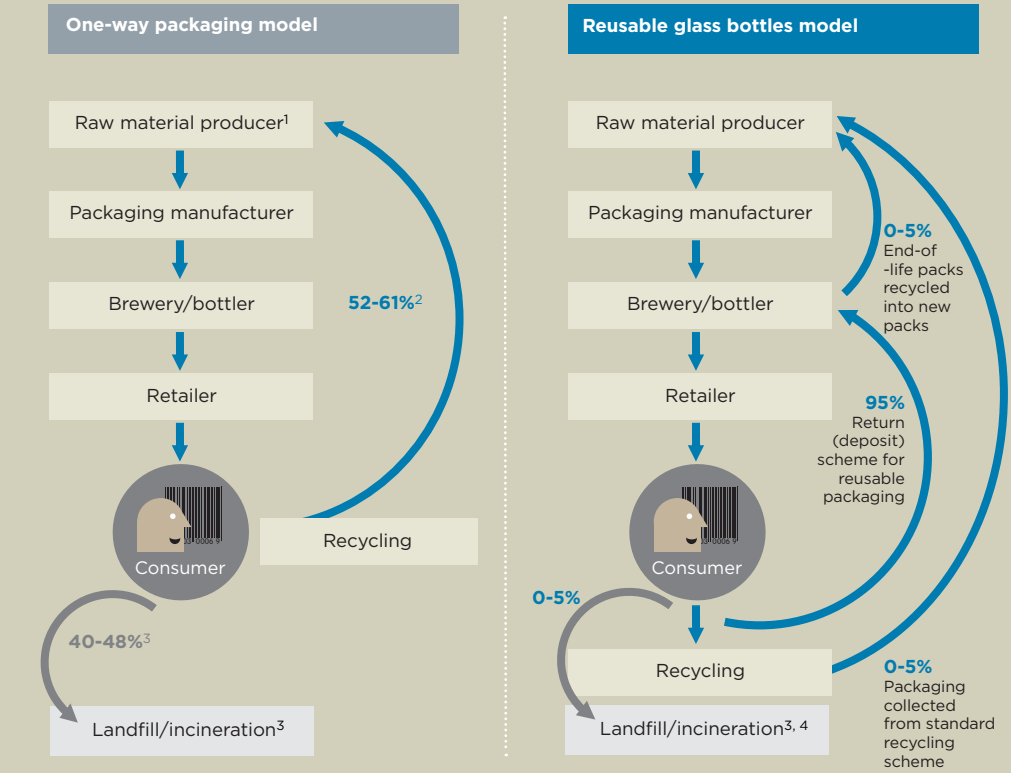
• Designing packaging for easy dismantling. Materials sciences and design institutes offer instructions and checklists to make packaging easy to take apart by adopting circular principles. For example, not using multiple polymers or mixing different types of materials that cannot be separated, such as glass and metals or plastics and paper, in one type of packaging. This is currently not an issue with most beverage containers, for example PET bottles, which typically have PP/PE caps to enable easy opening, can easily be separated in a float sink system due to different specific weights of the materials. However, if similar specific weights are used, or the material cannot be easily separated, it becomes more difficult.[134]

Even in a scenario in which all major materials can be separated, recycling on its own will not close the loop on packaging materials. Packaging will still account for a large share

133 The Grocery Manufacturers Association, Environmental Success Stories in the Consumer Packaged Goods industry, February, 2012.

134 Interview with Dr Klaus Stadler, Director Environment & Water Resources Europe, Coca Cola Europe

FIGURE 17 **Beer packaging shows potential for far greater circularity in many markets**



1 Example: PET resin, glass cullet, aluminium blocks
2 Recycling - Plastic bottles 52%, aluminium cans 60%, glass bottles 61%
3 Incineration ('waste to energy') of PET bottles, if done cleanly, is preferable to landfilling
4 Additional glass in municipal waste streams may be sorted in mixed-waste material recovery facility (MRF), but unlikely to be back into food-grade glass bottles due to regulations

SOURCE: WRAP, press searches, expert interviews, Ellen MacArthur Foundation circular economy team

of material consumption, especially given the rapid expansion of consumer goods in emerging markets. As discussed by Walter Stahel,[135] products with short lifecycles, a characteristic of many consumer goods, incur high material losses even when recycling rates are high. For example, aluminium drinks cans, which, in many European countries, are currently recycled at the high rate of 70%, still 'lose' more than half the original material within six months[136] (assuming a 60-day lifecycle from can to can[137]). Significant losses are incurred in the long loop for recycling used packaging back into the stream of packaging material inputs.

Designing packaging for reuse can bridge the gap to true circular systems (Figure 17).

Reuse—the power of the inner circle and circling longer

Circular systems that retain and reuse packaging in its original form are the gold standard for material savings:

• Power of the inner circle: Given inefficiencies along linear supply chains, tighter circles associated with reuse result in a higher substitution effect for virgin raw materials (due to lower material losses).

• Power of circling longer. Packaging designed for maximum reuse ensures huge material savings per unit volume of product consumed.

Analysis of a representative reusable-bottle system for beer showed, for example, that designing a more robust bottle (with 34% more material than a standard one-way glass bottle) allows up to 30 reuse cycles, offsetting the additional material cost 20 times over.[138]

Adopting new circular reusable models and maximising existing models for packaging represents a major opportunity for manufacturers, retailers, consumers and municipalities. Keeping packaging in circulation for longer will deliver dramatically greater material savings versus the traditional linear one-way system, especially if high collection rates can be ensured. Current informal collection systems in emerging markets are ideally suited to reuse schemes, while the growing online retail and home delivery trend in developed markets is suited to high collection rates for all types of reusable packaging as delivery trucks easily facilitate reverse logistics.

135 Walter Stahel, Founder-Director, The Product-Life Institute, Geneva, lecture at Surrey University - 'The drivers behind the shift from a linear to a circular economy' 16, February, 2011

136 Ellen MacArthur Foundation circular economy team

137 Novelis company website, 'The Recycling Process'

138 The Ellen MacArthur Foundation circular economy team analysis, SABMiller interviews, December 2012

3. How it works up close
Continued

What works well today?

Circular business models are in use today and deliver lower costs for manufacturers and consumers in both emerging markets and in ultramodern high-volume operations. In many markets, beverages are sold in refillable packaging, mainly glass. Depending on the market environment, refillables are a preferred packaging solution for many beverage manufacturers due to their generally lower carbon footprint and higher profit margins when compared to one-way packaging.[139] 47% of SABMiller's current global business for example, is in refillable bottles.[140] This is driven not only by the emerging markets of Africa, Latin American and Asian, but also by European markets.

The success of reuse schemes relies on a number of factors. First of all, a high cost of raw materials relative to other input costs encourages reuse as new materials are not required every time a beverage is consumed. Coca-Cola is typically able to cycle its glass bottles 35 – 45 times.[141] A second factor is low-cost collection and redistribution infrastructure, typically built on either efficient back-hauling in developed economies, or on low-cost labour and relatively short transport distances in traditional retail markets.[142]

MYTH
Consumer goods companies prefer to make large volumes of products in one-way packaging, selling them directly through big supermarkets

Reality: Some consumer goods companies would much rather use returnable packaging; they make money, save more material and have a lower total carbon footprint

Gabor Garamszegi, SVP Corporate Affairs for SABMiller Europe, says: 'We would generally prefer reusable glass bottles from both a cost perspective, as they may provide better margins, and a sustainability angle, given the material savings and associated lower carbon footprint [vs. one-way bottles]'

Previous investment in reuse infrastructure and the relatively low bargaining power of retailers, who tend to prefer the simplicity of one-way containers, are also factors likely to promote reuse systems. Finally, it also helps to have relatively undifferentiated packaging types (often with the same package used across different brands), as this reduces handling and processing costs of used bottles for both retailers and manufacturers.

In order to maximise the use of every bottle, high collection rates are required. In emerging markets, the relative value of the bottles provides a sufficient incentive for collection, further enabled by greater consumption of beverages on premises where vendors can retain possession of the bottles. In Africa, for instance, over 80% of beer is consumed on premises.[143] In developed markets, refillable systems are well established in high-volume, on-trade food and beverage settings where collection can be ensured (e.g., bars and restaurants with supply chains for reusable beer kegs and local brewer-bottled beer). While recent trends in developed markets have seen a significant move to consumption away from bars and restaurants for both beer and soft drinks,[144] opportunities still exist in the on-trade for companies to provide a better product experience and higher value for consumers via a closed-loop collection system.[145]

Expanding these solutions more widely represents an opportunity for manufacturers, distributors and collectors, and consumers. This can be illustrated by the case for reusable beer packaging (Figure 18). Our modelling of beer containers shows that shifting from a model of one-way glass to reusable glass beverage packaging would lower the cost of the packaging and all associated processing and distribution by approximately 20% per hectolitre of beer sold to consumers.[146] It has also been shown in various recent studies that not only can refillable bottles deliver a higher profit than one-way alternatives, they also have a considerably lower carbon (CO2e) footprint.[147] Although refillables are often resisted by retailers, some studies have shown higher footfall due to providing collection facilities for used bottles, and even higher basket spend per trip due to capturing consumers on their bigger shopping trips (e.g., superstore chosen for weekly

139 Interview with Peter Koegler, Senior Manager Environmental Value, SABMiller

140 Interview with Peter Koegler, Senior Manager Environmental Value, SABMiller

141 Interview with Dr Klaus Stadler, Director Environment & Water Resources Europe, The Coca Cola Company

142 Coca Cola micro distribution model- Coca-Cola website 'How Coca Cola is helping entrepreneurs in Africa to set up their own businesses http://www.coca-cola.co.uk/community/micro-distribution-centres.html

143 Canadean beer report 2012

144 Growth of soft drinks in Western Europe between 2001 and 2010 was 14% for off-trade and only 6% growth for on-trade, while for beer the difference was even greater: 24% for off-trade and only 5% for on-trade; Euromonitor value sales, 2001-2010

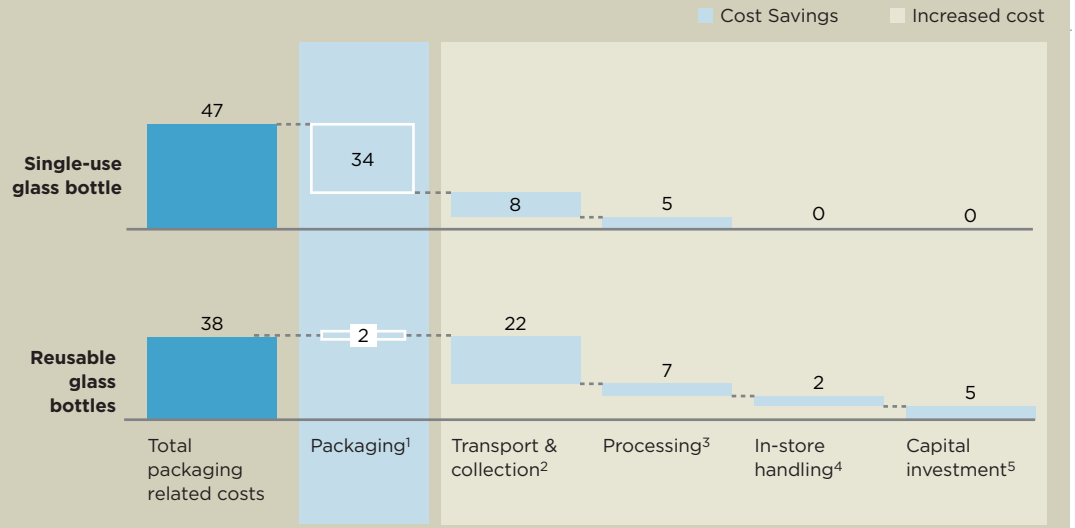
145 Interview with Jon Wilde, Global Packaging Sustainability Manager, Trinity Procurement GmbH, subsidiary of SABMiller plc, December 2012

146 Assumptions include 30 reuses per bottle, 95% return rate, 34% weight increase for reusable vs. one-way, 300 km average road miles from brewery to store and vice versa, USD 1.73/km transport costs, 1.14 reusable bottles required for each single-use bottle (bottle float requirement), USD 0.79 retailer handling costs per bottle

147 SABMiller carbon-intensity sensitivity analysis, July 2012, shows that returnable bottles deliver lower CO_2e than PET, cans, and one-way glass bottles (not publicly available information); PricewaterhouseCoopers, 'Reuse and Recycling Systems for Selected Beverage Packaging from a Sustainability Perspective', 2011, determined that unless transport distances exceed 600 km, reusables are more profitable and environmentally beneficial than one-way; The Beverage Industry Environmental Roundtable, June 2012, concluded that returnable bottles accounted for 13% of total footprint, versus 65% of total footprint for one-way bottles.

FIGURE 18 **Packaging: Reusable glass bottles offer approximately 20% lower cost than single-use glass bottles, driven by significantly lower material costs**

Comparison of single-use glass bottles and reusable glass bottles
USD costs of packaging per hectolitre of beer consumed



1 30 uses for recycable bottles, 95% return rate, 34% weight increase for reusable vs. one-way
2 300 km average road miles from brewery to store, £1.73/km transport costs
3 Filling costs equal for single and reuse bottles, washing/sterilising operating costs USD 0.8 cent for reusable bottles
4 Handling fee paid to retailers of USD 0.8 cent per reusable bottle
5 Reusable bottle float requires 1.14 reusable bottles to every single-use bottle; in-store collection infrastructure GBP 3,800 per store; brewer washing equipment USD 0.19 per hectolitre (depreciated over 10 years)

SOURCE: Expert interviews, WRAP, Ellen MacArthur Foundation circular economy team

shopping).[148] Retailers are already routinely using returnable transit packaging in place of cardboard boxes in their distribution network, but more work around 'retail-ready' or 'shelf-ready' packaging could still be done to reduce the amount of single-use cardboard.

In Canada, approximately two-thirds of beer is sold in reusable bottles—and the majority of brewers in Canada, large and small, use a common standard bottle, the industry Standard Mould Bottle (SMB). This, together with a return rate of approximately 97%, reduces costs versus one-way containers. The Canadian government initiated a shift of the packaging industry to adhere to an Extended Producer Responsibility (EPR) programme. This means that industry takes full responsibility (including costs) for disposing of packaging and other materials.

Beverage refilling opportunities also exist beyond beer and soft drinks. For imported goods, it will rarely make economic sense to return used packaging to the place of manufacture, but where volumes are high, both the economics and environmental considerations are likely to be favourable to bulk refilling—such as bulk imported wine that could be filled in returnable bottles.[149] Delhaize, a leading Belgian retailer, ships wine in bulk from various regions in France for filling into bottles in Brussels. A similar model has been suggested for the U.K., the biggest importer of wine globally at approximately 1.2 billion bottles per year.[150]

Other significant steps towards a fully circular system in consumer goods packaging are likely to include alternative models to the traditional bottle return and refilling systems. Greater adoption of in-store and in-home refilling systems would deliver significant material savings, as well as opportunities to provide consumers with a greater product choice and usage experience. Recent success stories include Sodastream in-home carbonation systems, with strong year-on-year revenue and profits growth since 2007.[151] Method, a U.S. business recently acquired by Ecover, has grown quickly on the back of concentrated and refillable detergents. In-store refilling has not yet taken off widely in the food and beverage sector due to the technical and food safety challenges that would need to be overcome. In other sectors, however, successful examples, such as paint mixing in the home improvement sector, have been in operation for many years. In the hospitality and food services sector, the success of Coca-Cola Freestyle machines—which provide over 100 different options and approximately the same footprint as an existing six- or eight-valve fountain dispenser[152]—demonstrates that innovative solutions can give both producers and retailers the opportunity to differentiate their offering, and deliver choice to consumers.

148 Movement Shopper Watch, Sweden, 2002

149 Economic analysis not carried out on bulk refilling of wine, but as suggested by Nicola Jenkin of Best Foot Forward, formerly of WRAP, 'bulk refilling of wine is surely the biggest packaging opportunity in beverages that we can solve'. Globally, the roughly 17.5 billion bottles of wine consumed annually account for 8.75 billion tonnes of glass—more packaging than any other product in the food or drink sector, http://www.wrap.org.uk/content/retail-drinks-category-wine

150 WRAP website ; section on retail drinks category http://www.wrap.org.uk/content/retail-drinks-category-wine

151 Financial Times Market Data : Sodastream International Ltd http://markets.ft.com/research/Markets/Tearsheets/Financials?s=SODA:NSQ

152 Coca-Cola Freestyle facebook profile https://www.facebook.com/cocacolafreestyle/info

3. How it works up close
Continued

Biodegradable[153] packaging can facilitate return of biological materials to the soil
As Ramani Narayan of Michigan State University puts it, 'There is no one easy end-of-life solution. Recycling makes sense when the article has value, can be readily collected, and easily cycled. [...] However, single-use disposable packaging and packaging in contact with food lend themselves to composting and anaerobic digestion as end-of-life options.'

Biodegradable packaging is favoured for applications where the packaging is used or in contact with organic materials (e.g., food residues), where it is difficult or uneconomical to collect it and separate (e.g., plastic films), or where it facilitates the recovery of food waste. Successful applications include biodegradable food waste bags that allow the return of food to the soil, or large-scale catering events, where single-use biodegradable packaging can be easily gathered up in order to return the more valuable organic materials for regeneration. Perhaps the most striking recent example was the London Bio Packaging contract for the 2012 Olympics Games. All food waste and an estimated 120 million pieces of packaging was readily collected in a contained system and industrially composted at an in-vessel composting site.[153] Contained systems such as large-scale events or fast food restaurants are ideal for ensuring the correct disposal route for packaging, because as Ramani Narayan says, 'As a consumer you cannot make a mistake if there are no mistakes to be made'.

The use of standard biodegradable plastics does not provide additional nutrients to the soil, but the materials do furnish the 'carbon fuel' for the microorganisms that digest the other organic matter.[155] Currently, many anaerobic digesters and industrial composters use expensive de-packaging machines to separate valuable organic waste from packaging. With advances in biodegradable packaging technology, processing, and the coupling of food with biodegradable packaging, such investments will become a thing of the past.

Some materials, e.g., mycelium, Ecovative Design's EcoCradle™ mushroom packaging, retain much of the nutrients of their plant-based material due to their distinctive manufacturing process (see sidebar), allowing considerable return of nutrients to the soil. Ecovative's packaging solutions have already achieved cost parity with conventional plastics, and are being successfully used to displace non-reusable or non-recycled materials such as expanded polystyrene. The potential drawback of using nutrient-rich biomaterials such as mycelium is that when collection and disposal options are not available, valuable biological material is taken from and not returned to the soil.

Biodegradability can also facilitate useful end-of-life processing options when collection for reuse or recycling is not feasible. Contaminated laundry in hospitals, for example, can be collected in biodegradable (PVA) bags—such as those developed by Harmless Packaging—and thrown straight into the washing machine where the bag dissolves harmlessly, avoiding unnecessary contamination and waste disposal.

Insufficient end-of-life options could be tackled by designing biodegradable packaging for multiple organic waste collection methods, such as disposal via a 'garbage disposal unit' in the sink (already present in 50% of U.S. households[156]) or through a washing machine; the organic waste could then be collected and processed into fertiliser products and/or biogas via existing waste-water treatment facilities. Feasibility would depend on the existing sewage infrastructure, the additional carbon load on the waste-water treatment system, and the relative cost and value captured versus organic waste collection trucked to anaerobic digesters or industrial composters.

For biological materials, biodegradable packaging could theoretically provide a fully circular system. For most applications requiring durability, however, the economic case still needs to be proved versus the established technical packaging materials such as glass or petrochemical-based plastics.

Bio-based materials, i.e., materials made from biological sources, but not necessarily biodegradable, should also be considered when designing the future packaging mix since they reduce reliance on fossil fuels and lower greenhouse gas emissions. However, companies that make bio-based materials must also take responsibility for the end-of-life process: it is not sufficient to make disposable bags out of bio-based polyethylene, but accept the littering, landfilling and loss of material from the biological system.

153 For the purposes of this report, where we refer to biodegradable, it is assumed that the material can therefore be readily decomposed under composting or anaerobic digester conditions in a short, defined period of time

154 Let's recycle website : 'Countrystyle composts packaging from Olympics' , 10 August, 2012 http://www.letsrecycle.com/news/latest-news/compost/countrystyle-composts-food-packaging-from-olympics

155 Ramani Narayan, Biobased & Biodegradable Polymer Materials: Rationale, Drivers, and Technology Exemplars; ACS (an American Chemical Society publication) Symposium Ser. 1114, Chapter 2, pp 13-31, 2012; Ramani Narayan, Carbon footprint of bioplastics using biocarbon content analysis and life cycle assessment, MRS (Materials Research Society) Bulletin, Vol 36 Issue 09, pg. 716 – 721, 2011

156 American Housing Survey (U.S. Census Bureau, 2009)

Mycelium—An innovate packaging solution

Ecovative's products are fully compostable alternatives to synthetic materials such as petroleum-based expanded plastics. They are made of mycelium—the 'roots' of mushrooms—which grow in and around agricultural by-products and can take any shape needed.

While observing mushrooms growing on wood chips, Eben Bayer and Gavin McIntyre, the founders of Ecovative Design, were inspired by how the mycelium, a fungal network of threadlike cells, bonded the wood chips together, acting like a 'natural, self-assembling glue'.

This observation spurred the team to formulate a new method to produce materials able to replace various types of products, including petroleum-based expanded plastics and particle board made using carcinogenic formaldehyde.

As Eben Bayer puts it, 'We're using mushrooms to create an entirely new class of materials which perform a lot like plastic during their use but are made using crop waste and are totally compostable at the end of their lives.'

They use parts of plants that cannot be used for food or feed and thus have a low economic value. The mycelium grows in 5 – 7 days without needing any light or water, digesting the agricultural by-product and binding into any shape needed.

'It is different from other biopolymers since you use the whole material, giving you a very high bio-efficiency', Eben Bayer explains.

This minimal processing reduces the cost of the product, making it economically viable; it has already reached cost parity with expanded polystyrene, a material that has had over 80 years to improve its cost structure. Additionally, the technique can use multiple feedstocks, thus allowing Ecovative to use locally available crops. The low-capital manufacturing process also means there is limited benefit to centralising production, and is readily compostable at the end of its use.

In 2010, Ecovative commercially launched a portfolio of protective packaging products, originally called EcoCradle™. Early adopters included Steelcase, a global manufacturer of office furniture, and Dell, a computer technology corporation. Since then, Ecovative have supplied their protective packaging to a growing number of other Fortune 500 companies. Ecovative is also investigating further applications, such as insulation and additional consumer products.

Since starting with two people 6 years ago, Ecovative has experienced very steep growth. It now has about 60-70 employees, opened a new factory a year ago and is planning additional plants in North America and Europe in the future.

MYTH
Biodegradable packaging could solve our problems with overflowing landfills and litter

Reality:'Biodegradable' is a bit of a misnomer

'"Biodegradability" as such is a meaningless term: it has no time frame', Dr. John Williams of NNFCC asserts. 'Most biodegradable packaging only degrades under specific conditions; it won't decompose for many years if left in a hedgerow. That's why the disposal system also needs to be defined'.

Ady Jager, of NatureWorks, asks: 'Unless you can capture other valuable materials [food waste], why would you deliberately degrade a material that could otherwise be reused or recycled after you've put so much energy into making it?' Many applications require, and benefit from, durability; this creates an inherent tension with biodegradability.

3. How it works up close
Continued

How can we scale up to full circularity?

A wide range of interventions are required to shift packaging from linear to circular systems, but all are already in place and operating up to country scale in some markets around the world.

Expanding packaging reuse systems requires changes to product design, setting up return distribution infrastructure and updating branding strategy:

• Designing packaging intentionally for durability and re-use (e.g., thicker walls and anti-scuffing technologies as opposed to the 'light-weighting' trend of single use).

• Updating current production, transport and retail infrastructure to process reusable containers at scale (e.g., back-haul collection of used containers, washing, refilling). Importantly, ubiquitous online and mobile usage will generate new opportunities here as wholesale/retail distribution infrastructure changes to accommodate new, possibly radically 'asset-light' lifestyles.

• Convincing marketers / business owners that they can convey their brand image and justify price points through reusable packaging. Notably, this varies widely by product category with often limited rationale, suggesting current behaviour is far more manufacturer-driven than truly serving consumer needs.

• Delivering technological development of in-store and at-home solutions for superior consumer experience and convenience.

Making biodegradable packaging commercially viable requires technological development, commercial scale-up and regulatory intervention:

• Further develop materials to deliver equal or better properties than technical materials at parity or lower cost—and at commercial scale—for applications where the system-wide economics make sense.

• Shift local authority spending from landfill to anaerobic digesters or industrial composters, e.g., via incentives or higher landfill taxes

• Develop anaerobic digester and / or industrial composter technology and operating procedures to readily turn biodegradable packaging into digestate or compost (e.g., facilitated via incentives for accepting biodegradable packaging).

As Marcus Hill, Founder and CEO of London Bio Packaging, says, 'There is a lack of infrastructure [for biodegradable packaging] and lack of volume. But this is changing in the UK. The general message from big waste management guys is that they can recycle / compost bio-plastics, but need the volume and incentives to do so. We are working with the waste management companies to help push forward this change'.

Encouraging manufacturers to take action could be supported by targeted regulatory standard setting:

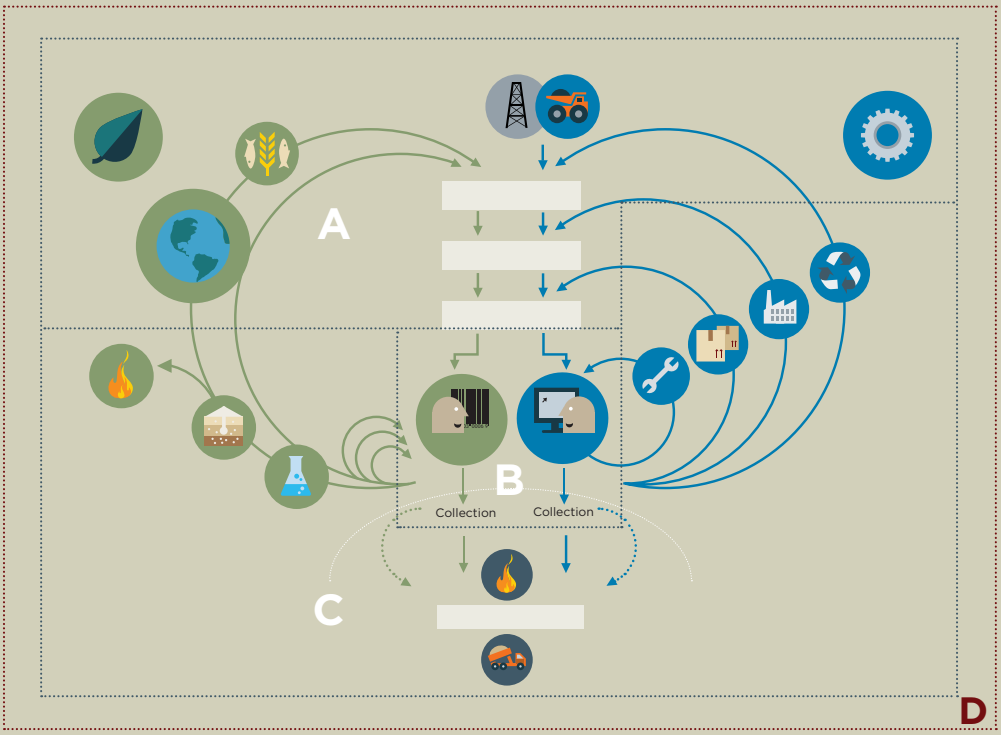
• Regulators could help accelerate the scale-up of circular packaging systems. Governments could converge on Extended Producer Responsibility schemes required to transfer the burden (or the incentive to innovate) to manufacturers. These schemes are already in place in many European countries and being adopted by more emerging economies, Zambia being a recent example.

• EPR would deliver better design of product packaging for reducing, reusing and recycling. It would also encourage investment in better end-of-life solutions—for example, collection, sorting and recycling infrastructure.

• Supporting regulation will be needed to ban toxic materials (e.g., PVC) and to modify accounting systems to price in externalities (e.g., landfill costs, energy consumption and carbon emissions). Taxes and mandatory deposits on single-use packaging are other examples where regulation has been used.

• Manufacturers could initiate cross-sector collaboration to spread the economic benefits for reusable systems across the value chain, since most savings are made by the manufacturer, while greater costs are incurred by the retailer.

FIGURE 19
Building blocks of a circular economy—what's needed to win



A

Skills in circular product design and production

- At the production level
- At the process level

B

New business models

- Acceptance and adoption by end-consumer
- Incorporation of new players within and across the value chains
- Information and visibility

C

Skills in building cascades/ reverse cycle

- Reverse logistics
- Technology

D

Enablers to improve cross-cycle and cross-sector performance

1. Develop and reinforce cross-value chain collaboration, joint product development and infrastructure management through

- Development of cross-value chain business models
- Develop visibility of material flow
- Industry standards Match-maker mechanisms

2. Rethink incentives
Align economic incentives

3. Provide a suitable international set of environmental rules

- Adapted certification programs
- More *extended producer responsibility* regulation

4. Lead by example and drive scale-up fast
Opportunities for governments to accelerate the spread of circular setups

5. Access to financing

- Development of private investors
- Access to financing facilitated for circular initiatives

SOURCE: Ellen MacArthur Foundation circular economy team

3. How it works up close
Continued

Putting it all together—building blocks of a circular economy

These examples—textiles, food processing by-products, post-consumer food waste, and packaging—show the need to scale up multiple elements, or a 'platform' to reach a full-fledged circular economy 'ecosystem'. The exact nature of this ecosystem and its building blocks is not yet certain, but the general skill sets and equipment required for the journey are increasingly clear (Figure 19).

1. Circular product design and production

Companies will build core competencies in circular design to facilitate product reuse, recycling and cascading. Circular product (and process) design requires advanced skills, information sets, and working methods that today are not readily available.

Material science and selection will play a critical role in *product design.* Manufacturers should specify the purpose and performance of the end-products, more than those of the input materials. They should also favour pure materials in their production process since they are easier to sort at end of life. Besides material selection, other areas important for economically successful circular design are standardised components, designed-to-last products, design for easy end-of-life sorting, separation or reuse of products and materials, and design-for-manufacturing criteria that take into account possible useful applications of by-products and wastes. 'We realised that laminates cause huge problems, so we are now setting new design parameters that reduce the number of substrates. It always comes back to design' says Richard Gillies, Marks & Spencer.

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 new product sales and other units aiming to reduce material consumption through remanufacturing and remarketing of used products). Since product and end-of-life system need to be better matched than they are today, there also needs to collaborate with country marketing and sales organisations so that valuable insights on the performance of local recycling and organics collection can flow back into the product design process. While much of the 'software' for the transition 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.

2. New business models

The shift to a more circular way of working is likely to require innovative business models that either replace existing ones or seize new opportunities. There is a need for first-mover firms and initiatives. Companies with significant market share and capabilities along several vertical steps of the linear value chain could play a major role in driving circularity into the mainstream by leveraging their scale and vertical integration. While many new models, materials, and products will come from entrepreneurs, these brand and volume leaders can also play a critical role. Profitable business models and initiatives will inspire other players and will be copied and expanded geographically.

Acceptance and adoption by end consumers. The success of new business models will be driven by the response of end consumers who are eager to adopt innovative ways of doing business. A rental scheme, for example, will require consumers to modify their habits—but in exchange for new benefits, such as new levels of choice and convenience. Acceptance will require raising awareness among consumers. Here, the big companies with well-known brand names have the most to gain (and the most to lose) and could take the lead and launch advertising and awareness campaigns to change mindsets and drive adoption.

Incorporation of new players within the value chain. Companies already in business may be the likeliest early adopters, as they are intimately familiar with their category's by-products, material losses and landfill charges.

But new players and 'outsiders' will also be needed in order to benefit from the injection of new inventions (e.g., Oberon's innovative filtering and conversion equipment to make fish meal directly from the waste water of food and beverage plants). They might either capture value directly by taking circular initiative or will facilitate the launch of new business model as a side-line to their core business, hence capturing part of the value that to date has been left on the table.

Information and visibility. To operate efficiently, the managers of most circular business models will need to maintain visibility of the full value chain—for example, of the by-products from different production stages. For this, working with an intermediary may help to enlarge the company's range of vision. Other business models will require quick access to information and good visibility of the material flow through the value chain. For example, an entrepreneur willing to broker the reuse of highly perishable brewer's spent grains will have to coordinate both with the breweries and with farmers to extract the grains value in time.

Capturing value is accelerated when a systems approach is applied to analysing opportunities. An example of this is the U.K.'s National Industrial Symbiosis Programme (NISP). NISP works to provide a brokerage service for businesses wishing to turn waste into by-products. NISP also plays a role in addressing technology and processing barriers to maximise economic benefits. Since its launch in 2000, NISP claims credit for bringing about cost savings of GBP 1 billion, additional sales revenue of GBP 993 million, and the creation of over 10,000 jobs in the U.K. economy.

On the consumer side, a new data driven application could be developed to focus on the collection of consumer data that would allow for many more commercial and non-commercial initiatives around collaborative consumption and other alternative business models to spring up. As James Moody, author of 'The Sixth Wave', puts it: 'While market signals are slowly aligning and technology factors are coming into place, the development of successful closed loop business models is still hampered by the lack of really good data on consumption behaviour'.

3. Skills in building cascades / reverse cycles

New and more skills will be needed for cascades and the final return to the soil or back into the industrial production system. They will certainly include delivery chain logistics, sorting, warehousing, risk management, power generation, and even molecular biology and polymer chemistry. With cost-efficient, better-quality collection and treatment systems and effective segmentation of end-of-life products, the leakage of materials out of the system will decrease, supporting the economics of circular design.

Reverse logistics chains to cascade materials to other applications will need to be optimised from beginning to end. It is therefore critical to build up the capabilities and infrastructure to move towards more circularity. Collection systems must be user-friendly, located in areas accessible to customers and end-of-life specialists, and capable of maintaining the quality of the materials so they can cascade through diverse applications. The 'downstream' applications should cascade in ways that optimise nutrients and value recovery, before finally returning nutrients to the soil.

Private companies can drive the development of regional solutions. A prominent and award-winning industrial scale valorisation business in France is currently run by Veolia Environmental Services (VES). As a biowaste solutions provider to the FMCG sector—specifically the food industry—it turns biowaste into certified composts and organic amendments, renewable energy, and liquid fuel. Partnerships with the farm business allow for stable and long-term markets for the compost.

Municipalities can (gently) foster the build-up of reverse infrastructure, with information events and suitable nudges in the form of city ordinances. This can go beyond allowing a company to set up textile collection banks up near a central traffic intersection. In Pune, India, cities have bylaws that all new buildings must be equipped with recycling infrastructure such as recycling rooms on each floor and sufficient space in the basement for separate containers.

3. How it works up close
Continued

Technology will allow optimisation of reverse logistics (e.g., textile sorting and tracking using RFID tags) and also innovative applications for reuse of materials (e.g., using BSG to produce ethanol). There will likely be demand for biochemists and molecular biologists able to recognise how the properties of a set of biological and technical nutrients in one industry can be successfully cycled through another industry value chain.

4. Enablers to improve cross-cycle and cross-sector performance

For widespread reuse of materials and higher resource productivity to become commonplace, market mechanisms will have to play a dominant role, but they will benefit from the support of policy makers, educational institutions and popular opinion leaders.

Expand and reinforce cross-cycle collaboration. Consumer goods companies that want to design products and services that are well-tailored to circular models, adopt new business models, and build effective and efficient reverse supply chains, cannot do this in isolation. They require new forms of collaboration with many other parties in their supply chain, sometimes of an entirely different size or nature. At times this can shake up the existing relationships and a new balance needs to be found. As Jean-Philippe Hermine, VP Strategic Environmental Planning at Renault, recounts: 'When we got involved in our suppliers' sourcing practices because we wanted them to use certain secondary raw materials, we basically interfered with an important source of how our they create margins. As a consequence the supply chain collectively needed to assess the new profit pools and learn to capture a different competitive advantage.'

Develop cross-value-chain collaboration. A successful circular economy requires companies to look outside their own value chain and build collaborations across value chains; bringing together companies (and individuals) that are not used to working together. Jean-Philippe Hermine at Renault notes: 'For reverse supply chains like the one in our ValTex textile recycling effort to work, a large group of very diverse players needs to be able to work together. There are synergies between different interests but there needs to be a substantial willingness to share.'

A critical element in cross-sector collaboration at scale is insight into how material flows of two entirely different value chains may be of relevance to each other. This starts with sufficient information on what waste or by-product streams are available. It may be company-internal teams that then go and find an application for these volumes, as is the case with Procter and Gamble's GARP team[157], or this matching up may be performed by a third-party service, such as a waste operator that has moved beyond the commodity business of waste haulage.

Rethinking incentives. '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. For example, in most developed economies, 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. Instead, they advocate shifting the tax burden away from labour/income and towards non-renewable resources. According to Walter Stahel: 'Taxing the consumption of non-renewable materials instead of labour will promote the local reuse of goods, components and molecules and thus reinforce the competitiveness of the value-preserving business models of a circular economy.'[158]

There is some evidence though that this idea is taking hold at long last. In its December 2012 'Manifesto for a resource-efficient Europe', the Members of the European Resource Efficiency Platform advocated such a tax shift (among other points):

'Abolishing environmentally harmful subsidies and tax-breaks that waste public money on obsolete practices, taking care to address affordability for people whose incomes are hardest-pressed. Shifting the tax burden away from jobs to encourage resource-efficiency, and using taxes and charges to stimulate innovation and development of a job-rich, socially cohesive, resource-efficient and climate-resilient economy.'[159]

157 GARP stands for Global Asset Recovery Purchases

158 From Walter Stahel's address to the World Resource Forum in Davos, Switzerland, September 2011

159 European Commission: 'Manifesto for a resource-efficient Europe' http://europa.eu/rapid/press-release_MEMO-12-989_en.htm

What will also help to quickly reach scale is regulation in the areas of consumer and corporate responsibility, accounting, certification, and standardisation.

Providing a suitable set of international environmental rules. Government and public sector entities can help to foster cross-chain collaboration by establishing standards and guidelines. Governments should re-examine certification programmes to enable new ways of confirming the viability or safety of circular products. As one example, limited certification guidelines currently exist for the use of the digestate from the anaerobic digestion process as a fertiliser. In a related vein, public authorities can also encouraging the shift from consumable to durable, for example, by making reusable beverage cups mandatory at music festivals and other large-scale events, all of which must currently obtain local permits to be held.

Regulation could push producers to be more responsible for the end of life of their products. This would provide greater incentives for deeper circular design of their business model.

One area that could greatly benefit from deeper government involvement is the preservation of soil fertility. A few governments have already started responding to the need for constant soil replenishment and a healthy balance of nutrients. In Ireland for example the government has put in place a comprehensive range of measures. One of the provisions of its 'Standards of Good Agricultural and Environmental Condition' is to maintain the organic matter content of soil above the critical limit of 3.4%. A number of agricultural funding mechanisms include soil fertility criteria and a fertility monitoring system is in place. Expert matter advice is available to farmers where needed.

Leading by example and driving scale up fast. There are many opportunities for governments to use their own procurement and material handling processes to accelerate the spread of circular setups. In the U.S., the policy of moving 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, 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 by making sewage available for reuse. There may also be a role for intermediate, 'convener' institutions in some countries (e.g., WRAP in the U.K.).

Access to financing. All players across value chains 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. Governments can create further funding stimuli by underwriting some of the risks associated with innovative businesses.

In Brazil, the Ministry of Agriculture, through the ABC program, gives access to preferred credit conditions to companies taking innovative initiatives.[160] Private investors are already investing in circularity and are doing so for profit. Another example is Climate Change Capital (CCC), a London-based investment manager and advisory group specialised in carbon finance. The fund is one of the largest in the sector with over GBP 1 billion invested, and is currently investing in anaerobic digestion in the U.K.

Besides direct government funding, public-private organisations also play a crucial role, for example in circular systems for soil nutrients. One example is the Nutrient Platform's program to 'close the loop' in Ghana. It is working on developing organic fertiliser products for the cocoa sector from different waste streams. Nutrient Platform's approach is strongly focused on business development, combining local and international private sector players on both the demand and the supply side.

While the list of enablers is long, the trends supporting a large-scale shift bode well. Both resource prices and disposal costs are rising, increasing motivation to find new solutions. Progress in technological and material development supports longer-lasting and more reusable designs, and increased visibility along the value chain enables all participants to better track products and materials.

160 Maximum USD 500,000 loan, over 5 to 15 years, at 5.5% - Money market rate is around 7.5%

3. How it works up close
Continued

A paradigm shift

Skills and education requirements must evolve to enable learners to grasp 'whole systems' design, a type of knowledge that is essential to create and develop a new bio-based circular economy.

> *'Synthesising and creating are also intellectual / cognitive capacities, and thus within the purview of school, and they are more important in the 21st century than ever before. But educators have less experience in training these "habits of mind" and unless teachers themselves have these latter skills, they will not be able to inculcate them effectively in students'.*[161]
>
> **Howard Gardner**
> Professor of Cognition and Education at the Harvard Graduate School of Education

The root of our existing educational system mirrors that of our economic system. Both emerged from the traditions and worldview 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 worldview is taking hold: a kind of revitalisation—an apt word, for many of its insights are based on insights from living systems—a 21st century Enlightenment.

The nature of the shift

The shift towards systems thinking is epitomised by the examples of the bio-based economy presented in this report. A systems-based scientific worldview recognises the importance of connection and flow, of dynamic equilibrium where feedback drives change and where the old one-way production system replete with waste is replaced by cascading materials. 'Waste = food' is the notion of capturing value in all of the flows and, importantly, of rebuilding natural capital to ensure enhanced flows. Just as the relationship of the part to the whole has reversed in emphasis, so, too, has our attitude towards natural capital: the emphasis is on regeneration and not degradation. Our new concern with the state of the whole in relation to the part replaces a largely exclusive focus on the part. As a result, bio materials are understood as a dependent part of a thriving whole, and products are optimised *within optimised systems*.

Education, at least in the formal sector and before the age of 19, is often seen as delivering specified content (knowledge) and defined skills. Learning is usually understood to result from teaching, and certification is thought to guarantee that at least a portion of that knowledge has been conveyed. It has been criticised for decades but it remains highly visible.

Recent work by educationalists Bill Lucas and Guy Claxton seems more in tune with a changing world. They advocate 'reframing discussion on skills in terms of developing dispositions and habits of mind'.[162] This connects with the thinking of Howard Gardner (quoted above) and with leading intellectual and business advisor Nassim Taleb who writes, 'Solutions can only come from simple heuristics. That's what we have been doing since civilisation began ...' The underlying sense in the term 'circular economy' is an attempt at such a heuristic, a framework for thinking.

The education system, if it remains true to the rationale of mirroring the scientific state of play and the economic concerns of dominant nation-states and leading institutions, will have to evolve to enable learners to grasp the 'habits of mind', the 'simple heuristics' and the 'dispositions' that enable effective 'whole systems' design. This spans products, technologies, and molecules, materials, and energy flows, and perhaps makes explicit those links between the subject specialties that are chronically underplayed at the present time.

Whole systems design demands a thorough rebalancing to make sure the specialist and general skills underlying systems design flow into one another, creating a richer understanding altogether.

161 Professor Howard Gardner (26th April 2012) OECD Education Today: Educating for innovative societies.

162 Bill Lucas and Guy Claxton 2010 New Kinds of Smart (Buckingham OUP Press)

The need to rebalance

The chart below summarises dimensions of education and training that need to be rebalanced. The headings in the left-hand column characterise the main approaches of the 20th century. The right-hand column indicates the directions in which we need to travel if we are to develop the innovative and adaptable school leaver who is able to acquire new 'habits of mind'.[163]

Systems thinking emphasises that skills have to be broadly understood. Even something as laudable as 'problem solving' carries with it an assumption that a problem is capable of being fixed. This can be true but often it is not: problem contextualising, looking for the systems and how to adjust system conditions might be more appropriate.

In dynamic systems, there is no fix, just intervention and review, an iterative process. As a consequence, since most real-life problems are contingent, solving them is much more likely to be a cross disciplinary effort—in business it would be decision-making units working as a team. In teaching and learning, the emphasis would be on opportunities for participatory learning and creative and critical thinking, above all.

Examples of rebalancing

20th century	21st century
Problem solving	Problem appreciation and reframing
Analysis	Synthesis
Reductionism	Whole system emphasis
Closed and immediate cause and effect	Multiple influences through time and space
Individual learning	Team or group learning
Being competitive	Competitive and collaborative
Emphasis on teacher transmitting pre-determined knowledge to the student	Learning through enquiry
Rooted in subjects or disciplines	Meta-learning[164]

163 See Bill Lucas and Guy Claxton (2009) Wider skills for learning. Centre for Real World Learning and NESTA

164 Meta learning was originally described by Donald B. Maudsley (1979) as 'the process by which learners become aware of and increasingly in control of habits of perception, inquiry, learning, and growth that they have internalized'. 'A theory of meta-learning and principles of facilitation an organismic perspective', Donald B. Maudsley, 1979

An economic opportunity worth billions

4

Describing the potential economic payoff of a rapid scale-up of circular business models in the consumer goods sector.

4. An economic opportunity worth billions

The ramifications of our choice between a linear or circular economic system extend well beyond resource sustainability. This choice will also affect the types of businesses that succeed, the products and services that consumers can choose, and the options for gainful employment.

This chapter highlights the significant potential benefits a circular economy can bring to each of the stakeholders involved, and how capturing these benefits can act as a catalyst to drive the transition. Of course, as with all major innovations, there will be individual winners and losers along the way–the rapid growth of a new company may come from winning share from an incumbent for example. However, we have conducted our analysis for the consumer economy as a whole, and here we hope to show:

How companies will win by tapping new and bigger profit pools, reducing material costs, addressing many industry-level strategic challenges, and building greater resilience as a result.

How economies will win from the improvement in net exports, lower price volatility, enhanced supply security, and the creation of local job opportunities in new businesses. Job creation will reduce benefit payouts, increase tax income, and improve GDP, while enhanced innovation from the circular economy will have further intangible benefits.

How natural capital will win through reduced pressures on the food value chain and preserved and improved land productivity.

How consumers will win from greater utility as a result of more choice, lower prices, and lower total cost of ownership.

How companies will win

Companies are set to win in two ways. Firstly, the circular economy can help drive growth, in particular by opening up new and bigger profit pools in existing industries. Secondly, it will help address a number of the pressing strategic challenges that consumer businesses are facing today. These include fragmentation of markets into micro-markets with (locally) specific demand patterns and supply chain requirements, which are more expensive to serve. Value and revenue are being lost to second-hand markets as well as to new channels and more informal exchanges. Most consumer companies have experienced a persistent lack of growth in mature markets in the face of increasing resource prices, exerting pressure on margins. As commodity businesses, consumer goods generally have low barriers to switching, but with digital media it is easier than ever for consumers to compare offers and prices online and with family and friends, pushing up churn rates and the costs of customer retention. Finally, while global sourcing has given businesses new ways to reduce purchasing costs, it also extends supply chains into delicate hemisphere- or planet-spanning networks, in which delivery (or not) may hang from a thread.

New and bigger profit pools
In Chapter 3, we described how individual businesses could achieve lower input costs and in some cases create entire new profit streams in some of the largest sectors in the consumer goods industry. Winners are already emerging, supporting ongoing migration towards a more circular economy. We believe similar opportunities are likely across the consumer landscape, some of which will be stimulated by the following developments.

New business opportunities due to systems redesign/rethinking and co-location. Any increase in materials productivity is likely to have an important 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 framework, capable of sparking creative solutions and boosting innovation rates. New businesses using cascaded materials are one clear instance.

As demonstrated in our examples, attractive opportunities exist for companies to add new downstream businesses. These will profit from the dual benefits of extracting additional value from the cascaded material as input while avoiding waste costs. Both benefits are likely to increase as the cost of landfilling rises, regulations tighten, and available landfill space decreases. Development of the relevant technologies and capabilities will open up new pathways, and reduce the costs of those that already exist.

Collection and reverse logistics. Our examples highlight the importance of explicitly designing collection and reverse logistics as integral parts of an overall system that aims to increase materials productivity by reworking end-of-life products. Around the globe, classical waste management operators such as Veolia, CIWT and Abengoa are increasingly diversifying the fractions they handle and diverting them from landfill towards more recycling and even refurbishment operations. Logistics service providers are increasingly treating reverse logistics not only as a way to fill backhaul loads but as an attractive standalone business. DHL, for instance, picks up the recyclables of over 800 JD Wetherspoon pubs when it makes deliveries there, and is growing its waste-related services under the Envirosolutions brand. It has also established a beverage distribution platform in the U.K. that includes the distribution, refilling, repair, and collection of vending machines.

Increasing circularity often creates new opportunities for localised integration to make use of by-products, which can create whole new local industries that would not otherwise be feasible in high-income countries. Examples are tomato greenhouses that profit from waste heat in a nearby CHP plant,[165] or German farmers who diversify into fish farming—where heat is a major part of the costs—by using waste heat from their farms' shared biogas plant.[166]

Financing for R&D. Individual companies and groups will need funding for R&D and new technologies. As in the linear economy, the financial sector has an important role in the circular economy. Incumbents typically have large R&D budgets to develop incremental optimisation on linear systems whereas circular businesses are just starting to emerge and have not yet reached scale. Banks could help as they are typically far more experienced in understanding risks and therefore better at structuring long-term return models than corporations alone.

Product remarketers and sales platforms. While providers of sales and remarketing services in the durables space are rapidly expanding and growing into substantial enterprises, in the food industry it is especially micro businesses that are drumming to a different beat. Across different industries, the idea of 'collaborative consumption' has become a popular part of social media culture, especially as well-designed platforms do not ask consumers to leave their comfort zones. Network technologies and social media are dramatically increasing their reach and reducing distribution costs for providers of sales and remarketing services. In the consumer-to-consumer environment, eBay and Craigslist led the way for second-hand goods traded online. For clothing there is a growing number of dedicated sites that focus on different models of sharing. Some more specialised companies are offering sales platforms in the business-to-business environment, such as the Waste Producer Exchange[167] in the U.K., which is open to any registered user who wants to sell waste products and materials.

Solutions for more resilience and competitiveness

An emphasis on circularity could address multiple strategic challenges currently faced by consumer goods companies, such as greater volatility, declining customer loyalty, and the burden of costly waste disposal. 'Closing the loop' in the circular economy essentially requires much closer and more extended collaboration between participants. Consumers also become much more integrated because the value chain does not end at the consumption stage.

Reduced volatility and greater security of supply. Because the shift to a more circular economy implies using less virgin material and more recycled inputs with a higher share of labour costs, it will tend to reduce

165 Houweling's Tomatoes in Camarillo, California, is a 125-acre tomato grower in California using a first-of-its kind combined heat and power (CHP) system to provide electricity and hot water for its greenhouses, as well as carbon dioxide (CO_2) for fertilising the plants. http://www.sustainablebusiness.com/index.cfm/go/news.display/id/24000

166 NDR: In Soltau kommt Zander aus dem Schweinestall, 21 March 2012

167 http://www.wasteproducerexchange.com

4. An economic opportunity worth billions
Continued

a company's exposure to ever more volatile raw materials prices, increasing its resilience.

The threat of supply chains being disrupted by natural disasters or geopolitical imbalances is lessened, too, because decentralised operators provide alternative materials sources. As Jean-Philippe Hermine at Renault remarks: 'By reusing material, you disconnect from market price volatility and secure supplies'.

Both natural and synthetic fibres, for example, have a strong correlation with energy prices, which has led to price surges and higher volatility. This is an important issue for clothing producers as materials input is 9% of the cost of a garment, on average. Replacing a larger share of inputs with cycled materials would reduce clothing manufacturers' exposure to the volatility[168] of raw materials prices. Establishing a reprocessing industry would therefore be a highly advisable strategy for countries that currently import large quantities of raw material in the form of cotton and synthetic fibres as inputs for the textile industry.

Mineral fertilisers are another example where the local nature of many circular businesses should have a dampening effect on price volatility. Fertiliser prices are set globally, as the products are easy to transport and depend on globally traded commodities such as natural gas. Prices have been highly volatile in recent years, causing uncertainty for farmers as fertilisers and crop protection accounts for a large share of farm operating costs (40% for cereals production in the EU).[169]

Improved customer interaction and loyalty. Circular solutions offer new ways to creatively engage consumers. 'Instead of one-time transactions, companies can develop life-time service relationships with their customers', says Lauren Anderson, Innovation Director at Collaborative Consumption Labs. The new 'Coca-Cola Freestyle' soda vending machine offers consumers a very large choice of flavours, but has the footprint of just a few packages of Coke. With rental or leasing contracts in place, companies can gather more consumer insights for improved personalisation, customisation, and retention. Providing end-of-life treatment options and incentives to use them could increase the number of consumer touch points. This is especially true for businesses that rely on consumer participation, for example to separate waste such as Brantano, which periodically runs 'new for old' program in their shops to collect used shoes in exchange for discount vouchers. Here again, systems can only work if they offer mutual benefits.

New business models such as rentals establish a longer-term relationship with consumers, as many more interactions take place between consumers and companies over the lifetime of a product. This offers companies the chance to gain unique insights into usage patterns that can lead to a virtuous circle of improved products, better service, and greater customer satisfaction.

Circular models could also result in better alignment between the interests of consumers and companies, increasing customer satisfaction and loyalty. One example is the durability of clothes. The trade-off for the company in a linear system is customer dissatisfaction versus the potential to sell a new piece of clothing. In a circular system, where consumers can return clothing for inexpensive/free repairs, companies and consumers both have an interest in preserving the utility of the product.

Another important point is that consumers care about waste, and addressing it proactively can have reputational benefits. In 2012, H&M was humbled when it was found to have been mutilating and then disposing of clothes it had been unable to sell in order to keep them from turning up on the grey market. Public outcry forced management to halt the practice.[170] Food waste is a particularly emotional topic, and illustrates how deeply a company's reputation can be affected by their action on this issue. A recent Unilever study showed that a large majority of people (94% in China, 96% in Brazil and 72% in the U.S.) do care about the environmentally friendly disposal of food waste both at home and when eating out.[171]

Optimisation of materials recycling systems. Some materials recycling and composting systems are already well established. They typically take the form of regionally

168 'Soaring polyester puts squeeze on fashion', FT, April 2011, and 'Cotton prices surge to all-time high', FT, Feb. 2011

169 Farm Economics brief N°2 - EU production costs overview, European Commission on Agriculture and Rural Development

170 H&M says it will stop destroying unworn clothes', New York Times, 6 January 2010

171 Unilever, Sustainable Kitchens: Reducing food waste—World Menu Report global research findings, 2011

ESTIMATE

FIGURE 20 **Adoption of circular setup in relevant fast-moving consumer goods sectors could yield net material cost savings of USD 595 – 706 billion per year at a global level**

Net material cost savings in consumers industries
USD billion per year, based on total material savings from consumer categories[1], Global



1 Input costs derived from consumption and percentages of material input for each category
2 Other includes consumer health, pet care, home care, and tobacco

SOURCE: Euromonitor 2011,
Ellen MacArthur Foundation circular economy team

structured multi-user organisations (such as the many product-category-specific systems in Europe, from batteries to packaging) or are company-specific such as Nespresso's collection and recycling of spent capsules. Both group and single-company solutions require a standard purity level suitable for high-quality recycling processes. Consequently, the market has generally developed into regionalised, specialised players with natural barriers to growth beyond their initial footprint.

A number of companies have nevertheless started to enlarge the scale and scope of their operations by adding new regions and further materials fractions to their portfolio. Tomra has used its technological capabilities to supply the technology for large-scale, nationwide collection schemes (e.g of PET bottles). The company has grown at close to 20% per annum. Looking ahead, it plans further improvements in technology to reduce the burden of costly separation and pre-sorting schemes and therefore aims to achieve higher recycling yields at lower cost, resulting in rapid and profitable growth for recyclers.

How economies will win

Beyond its fundamental value creation potential over the next 10 to 15 years, a large-scale transition to a circular economy promises to fundamentally address some of the economy's long-term challenges. A circular economy could cut net materials costs and reduce price volatility and supply risks. Local job creation will be another important benefit, alongside greater innovation and greater resilience. Importantly, the greatly reduced materials intensity and lower energy demands of the circular economy offer a viable contribution to climate change mitigation and fossil fuel independence, making it easier to cross the threshold to a production base that largely runs on renewable sources of energy. Moreover, the decoupling of growth from the demand for resources will also slow current rates of natural capital erosion, as the next section argues.

Substantial savings on net materials costs. This report estimates that the circular economy could represent an annual materials cost savings opportunity of USD 706 billion or a recurring 1.12% of 2010 GDP, all net of materials used in reverse-cycle processes. This breaks down into the categories shown in Figure 20. In these scenarios, the savings would represent ~ 20 percent of the material input costs incurred by the overall consumer goods industry.

These figures are intended to demonstrate the order of magnitude of the savings that could be expected in a circular economy. Since the full effect of circularity for the entire economy is highly dependent on many factors such as industry structure and conduct, elasticity, and companies' drive to reap circular potential, we chose to ground our estimate on the potential materials savings observed for the products in the examples examined in Chapter 3 and extrapolated those to the rest of the fast-moving consumer goods categories.

4. An economic opportunity worth billions
Continued

Similarly, our analysis only covers materials 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 is likely to vary across sectors and regions and therefore defies exact prediction. The order of magnitude identified confirms that we are looking at a substantial opportunity for the economy as it is founded on a structural and therefore lasting shift—a restorative circular economy.

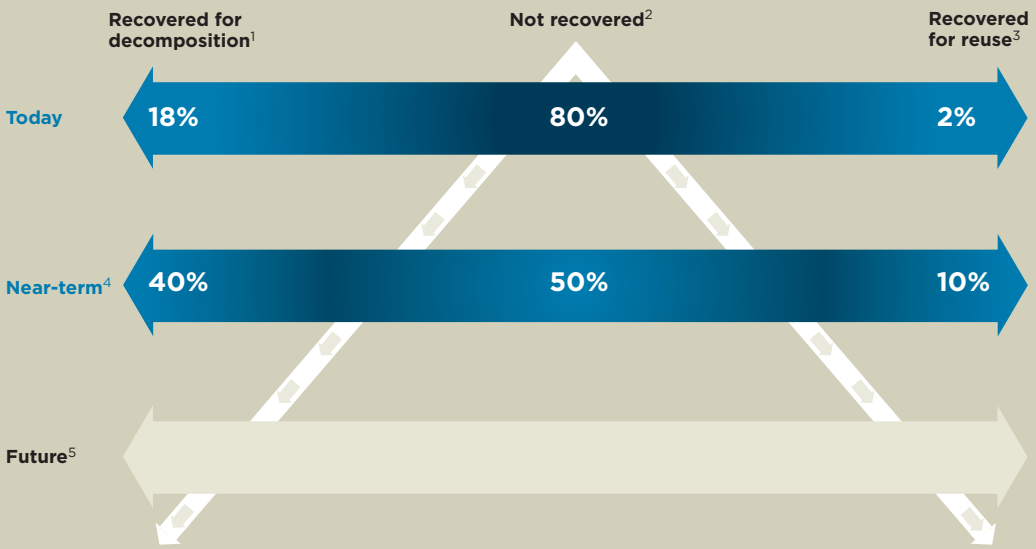
As shown in Figure 21, by applying these circular practices in the near term across the consumer sector, 30% more materials could be recovered than are recovered today. The opportunities lie in both decomposition (cascading, recycling and return of nutrients to the soil) and in reuse of materials.

We expect significant economic potential for circular business models in both developed and emerging markets. As a starting point, emerging market economies are often not as locked into existing manufacturing or infrastructure development models as advanced economies are, and thus have the chance to leapfrog straight into circular setups when building their infrastructure sectors. Many emerging economies are also more materials-intensive than advanced economies and thus could expect even greater relative savings from circular business practices.

Local solutions can offer a degree of decoupling from volatile global markets, as substitution by recycled/reused and cascaded material lessens the need for virgin inputs, reducing imports and dependence on the global materials supply chain.

Reduced pressure on scarce natural resources, lower GHG emissions. Further benefits accumulate in terms of reduced externalities, such as GHG emissions, water, or toxic substances (Figure 22). A growing number of countries are developing low-carbon growth plans and are investing to reduce greenhouse gas emissions and address a range of environmental issues.

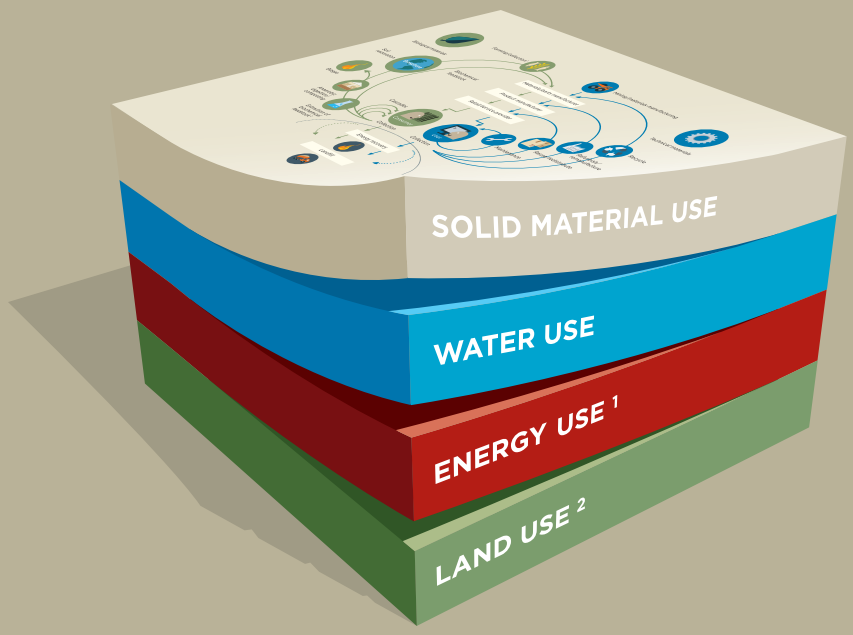
FIGURE 21 **Path to a circular economy—design and recover consumer goods for reuse or decomposition**
% of FMCG products (by value)



1 Decomposition to allow materials to be recycled or biodegraded, depending on product/packaging material characteristics and end of life collection
2 Cannot be reused, recycled or biodegraded due to poor design and/or lack of end-of-life collection options
3 Reuse can include direct reuse for the same or different value streams or industries
3 Economic feasibility demonstrated in this report
4 Economic feasibility not yet proven

SOURCE: Euromonitor 2011, Expert interviews, Ellen MacArthur Foundation circular economy team

FIGURE 22 **The impact of more circular production processes accumulates across several layers of inputs**



1 Including greenhouse gases
2 Including impact on soil health/fertility, biodiversity, and ecosystem services

The circular economy will relieve environmental burdens by reducing the need for landfill and decreasing the public costs of waste treatment (a severe burden on the state as these costs are often not covered by the companies that make or process the items that end up in those landfills). Realising the full benefits of the circular economy from the specific examples we have investigated—clothing, consumption food waste, food processing waste, and packaging—would globally divert up to 340 million tonnes of waste from landfill each year, of which more than 80 percent would be from the elimination of food waste alone. These savings are equivalent to 2.5 times the municipal waste the U.S. generates each year.[172]

Where GHG emissions are concerned, the impact could also be substantial. If food waste were diverted from landfill and the energy from food waste-derived biogas was used as a replacement for natural gas, total savings of 580 kg of CO_2e per tonne of food waste could be obtained.[173,174,175] The resulting savings in emissions from household, retail, and hospitality in the U.K. for example would amount to 7 million tonnes of CO_2e. Additional greenhouse gas reduction benefits are gained from replacing mineral fertiliser and using the heat from anaerobic digestion.

Greater job creation. Sectoral shifts will allow employment creation in new downstream businesses. In a recent report, the McKinsey Global Institute analysed the underlying reasons for the 40 million people who are unemployed in developed countries. The report found that 'increasingly, jobs that are created are in research and development, product design, engineering, and marketing, whereas most unemployed people are unqualified and require relatively less skilled jobs. While training can help redress this imbalance, new entry-level semi-skilled jobs are also needed to replace the factory jobs that the linear economy has out sourced to the developing world.

While some of the jobs created by the circular economy are highly skilled, such as in technology development and research, a large share of the job creation is also for unskilled labo ur, addressing a major problem of developed countries, where such positions are becoming increasingly scarce. 'The diverging fates of high- and low-skill workers are seen across the OECD: the share of employed workers who lack an upper secondary degree has declined by one-third since 1995',[177] the report finds.

Collection and sorting activities to enable the reverse cycle are expected to create additional jobs locally. The head of the French Environment and Energy positive influence on the soil's water balance. Regenerative agricultural systems typically pay special attention to water management and improve water balances through such design elements as crop choice, field layout, and landscape elements.

Management Agency says that 28,000 jobs have been created in France over the past 20 years in collection and sorting in the

172 US EPA: 2010 MSW characterization fact sheet and data tables, November 2011 Municipal waste stream includes waste from both households and businesses. Municipal solid waste does not include construction and demolition materials, municipal wastewater treatment sludge, or non-hazardous industrial wastes

173 Ecoinvent: The ecoinvent database, version v2.2, 2012

174 Emissions in the value chain of the food are not taken into account, as waste can be considered burden free (IPCC)

175 WRAP, Waste arisings in the supply of food and drink to U.K. households, 2011

176 McKinsey Global Institute: Help wanted: The future of work in advanced economies, 2012

4. An economic opportunity worth billions
Continued

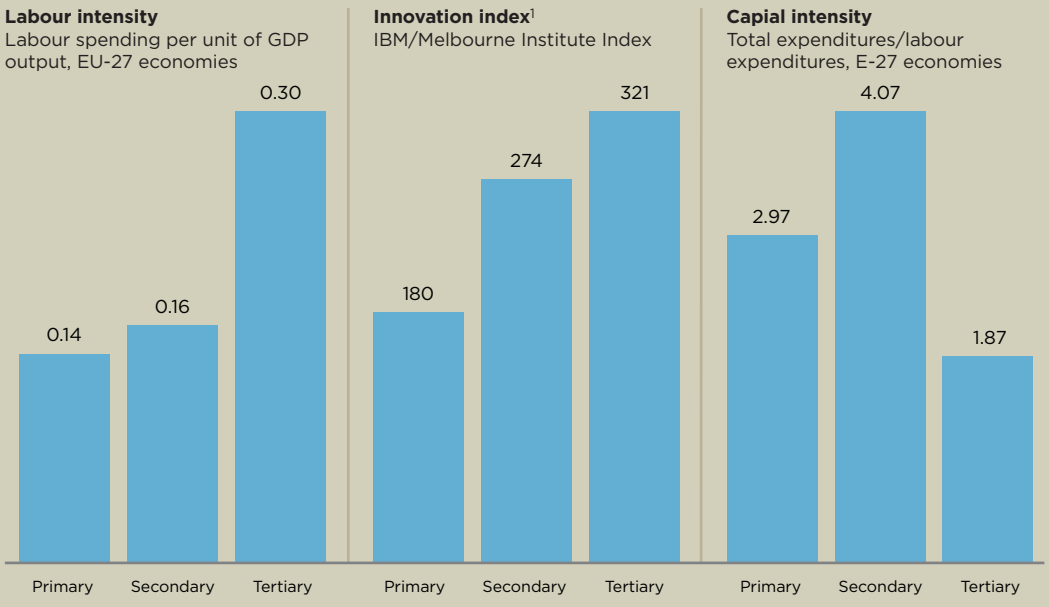
packaging sector alone.[178] Sita Group, the waste management arm of Suez Environment, estimates that some 500,000 jobs have been created by the recycling industry in the EU. This number could well rise in a circular economy. Clothes recycling, for example, will continue to rely on manual sorting. While technologies are starting to emerge to sort textiles by type of fibre, human judgement is required to sort clothes into around 160 different categories according to what would be most appropriate for different markets.

Anaerobic digestion (AD) will create jobs not just at the plants themselves, but also in logistics and at technology providers and related services, like quality testing. Anaerobic digestion relies on local feedstock, heat sinks, and agricultural land to distribute the fertiliser, and therefore plants are limited in size (AD plants typically produce 1 - 2 MW, compared to 1,000 MW for a big coal or nuclear power plant). As James Russell from Tamar Energy puts it: 'AD creates more jobs per MW than any other energy technology'. Defra estimates that 35,000 new jobs may be generated from the use of AD technologies in the U.K.[179]

Systems for reusing bottles also create jobs. A study of the German system—with a large proportion of both reuse and one-way packaging (reusable bottles accounted for a share of 73% at the time of the study)—shows that production, filling, distribution, and retail employs 161,000 people. The study concluded that 'going linear'—i.e., switching to a completely one-way packaging system for beverages—would lead to the loss of 53,000 jobs, whereas increasing the share of reusable packaging to 100% would result in 27,000 additional jobs.[180]

Economic benefits from enhanced innovation. Given the strong fundamentals of the underlying business case (assuming shifts such as comprehensive design changes to products, service delivery processes, and technology), adopting more circular business models would yield significant benefits, including greater innovation across the economy (Figure 23). While the exact GDP implications of greater innovation across an economy are difficult to quantify, benefits include higher rates of technological development; improved material, labour, and energy efficiency; and more profit opportunities for companies.

FIGURE 23 **Revamping industry, reducing material bottlenecks, and creating tertiary sector opportunities would benefit labour, capital, and innovation**



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

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

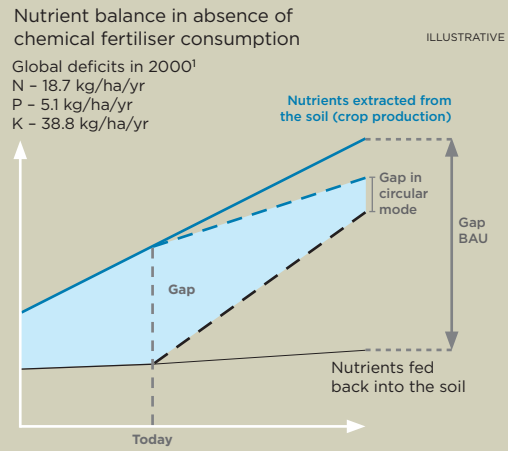
177 McKinsey Global Institute: Help wanted: The future of work in advanced economies, 2012

178 '28 000 emplois créés en vingt ans', Libération, 3 December 2012

179 Anaerobic digestion strategy and action plan – Defra (2011)

180 Golding, Andreas. Reuse of Primary Packaging. (Main report) Brussels: European Commission, 1998, referencing previous report by same author Golding Andreas, Schaffung und Erhalt von Arbeitsplätzen durch Mehrweg, in Neue Wege ohne Abfall – Tendenzen, Fakten, Strategien, Iför, Berlin, 1993

FIGURE 24 **Circular economy principles could help regenerate soil to replenish natural capital**



1 Z. X. Tan, R. Lal & K. D. Wiebe (2005): Global Soil Nutrient Depletion and Yield Reduction, Journal of Sustainable Agriculture, 26:1, 123-146
SOURCE: Ellen MacArthur Foundation circular economy team

Reduced budget pressure on municipalities that can generate revenue from household waste. Municipalities can generate revenues from their waste collection systems. Our estimate for an American city of 1.5 million inhabitants shows that it could generate profits of USD 13.7 million p.a. from better sorting, not including landfill costs, or roughly USD 9 per person. Scaling that up globally would correspond to profits of USD 64 billion for municipal budgets.

How natural capital will win

Circularity reduces the pressures on agricultural assets and the preservation of land productivity through the return of nutrients to the soil.

Less pressure on food production. Given that around one-third of the total food produced for human consumption is now lost or wasted, using this 'waste' material in place of virgin agricultural output has substantial potential to slow the growth in demand for land and ease the strain on land that is already under cultivation. Similarly, the use of secondary materials in other consumer goods reduces the need for virgin materials and hence—in the case of plant- or animal-based materials—for land. Avoiding the use of marginal lands for farming will further curtail the need for additional fertilisers and water.

Preserved land productivity. Land productivity is a complex function of the balance of nutrients in the soil, its structure and organic matter content, farming techniques, surrounding ecosystem, climatic conditions and available irrigation.[181] Soil formation is a very slow process: under natural conditions an inch of topsoil takes thousands of years to form—as laid out in Chapter 1, this is no match for our current high-yield agricultural practices, which tend to erode topsoil and deplete nutrient levels. In our linear system we deploy chemical fertiliser to restore and improve nitrogen, phosphorus, and potash levels. Circular, regenerative practices, however, maintain and improve the full range of macronutrients and micronutrients, as well as carbon levels. The content of organic matter in soil is also very important for soil texture, influencing water retention and nutrient delivery to the roots of plants, which is critical for plant growth. Chemical fertilisers do not supply organic material, while manure and compost have varying but typically high shares of organic matter. While reports differ on the exact water-holding capacity of soil organic matter, there is agreement on the fact that the amount of organic matter in a soil directly influences the availability of water to a crop over time—and hence crop yield.[182] The addition of manure and compost also helps in balancing the soil pH, which is a limiting factor for nutrient absorption and balance. For most crops nutrient uptake is best when soil pH is near neutral.

The circular economy maintains high levels of nutrients and soil carbon by both ensuring that organic wastes are returned—uncontaminated—to the soil, and by deploying a broad set of agricultural practices that reduce the speed of erosion.

The circular economy will reduce the need for chemical fertilisers and soil amendments to replenish the soil by *processing and feeding back much more biological material* via (for instance) anaerobic digestion—the principle of regeneration (Figure 24 illustrates this for NPK nutrients). In theory, the organic sources of NPK fertiliser outlined in the sidebar could together contribute nearly 2.7 times the nutrients contained in today's total chemical fertiliser volumes. This is the theoretical maximum, however, and further analysis is needed to assess what share of organic fertilisers could be returned to the soil in a cost-effective way.

Ample attention is given to a more extensive set of restorative agricultural practices—borrowing from both the latest insights in agricultural science and engineering and century-old (and re-discovered) principles such as those underpinning permaculture systems. The sidebar illustrates a small selection of such practices. Like the return of carbon to soils, fertility-preserving agricultural practices will also have a positive influence on the soil's water balance. Regenerative agricultural systems typically pay special attention to water management and improve water balances through such design elements as crop choice, field layout, and landscape elements.

181 Impact assessment of the thematic strategy on soil protection – Communication from the European Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the regions

182 Compost increases the water holding capacity of droughty soils--How to choose compost that increases the soil's water holding capacity. Posted at http://msue.anr.msu.edu/news/compost_increases_the_water_holding_capacity_of_droughty_soils on July 20, 2012 by M. Charles Gould, Michigan State University Extension

4. An economic opportunity worth billions
Continued

Urban farming: providing the missing link?

Co-location is often an important prerequisite for closing loops as some material and energy waste streams are difficult or prohibitively expensive to transport over larger distances (such as waste heat or wet fertilising material). As vertical and other forms of urban farms and processing capacity are situated near urban centres, transport distances are reduced. This reduces costs, energy, and the food's carbon footprint—and fosters local sourcing and the supply of fresher food, two growing demands on today's grocery retailers.

Worldwide, many projects are being developed that integrate agriculture, food production and energy generation processes so that waste from one process can be immediately reused in another. This can take many forms, from micro-scale rooftop gardens and greenhouses to small-scale, urbanized forms of 'industrial or commercial symbiosis' to drastically different concepts of agricultural production that basically decouple output from land use.

'The Plant' in Chicago is a good example where the discarded materials from one business are used as a resource for another—industrial symbiosis. This vertical farm and food incubator plans to house artisan food businesses, including a beer brewery, bakery, kombucha (fermented tea) brewery, mushroom farm, and a shared kitchen. The spent grains from the brewery are fed to tilapia fish, while solids from the tilapia waste are fed to the mushrooms.

PlantLab in the Netherlands does away with the concept of land-based agricultural production and even traditional greenhouses, instead optimising crop cultivation in fully controlled closed buildings based on three principles. One is vertical farming: plants are cultivated on multiple floors of city buildings. The second is special LED lighting that only provides the wavelengths essential for growth: no energy is wasted on unnecessary light spectra. Third, mathematical models are used to optimise growth inputs and combined with economic calculation models.

Vertical and other forms of urban farming will likely always play at a different scale than large industrialised production, but together with such industrial-scale and other small- and medium-scale production systems it makes up a system of nested circles, mutually increasing the agricultural system's resilience overall.

Alternative sources of nutrients

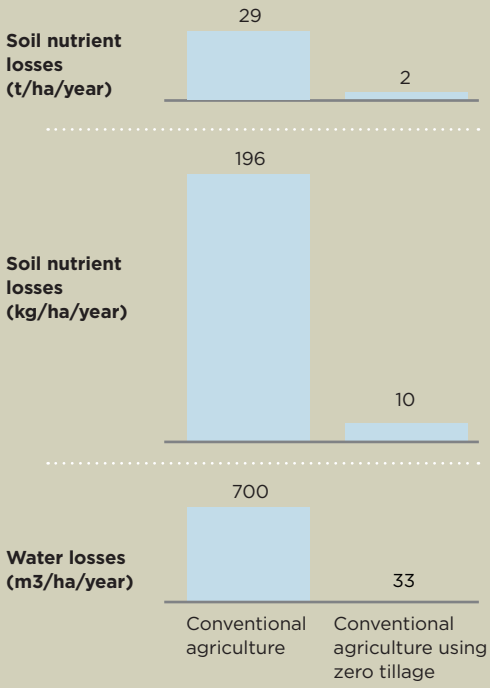
Return of food waste: If 100% of consumption-related food waste and 50% of other food waste generated today was put back into the soil, it could replenish 5 million tonnes of nitrogen, phosphates and potash (N, P, K), substituting for 4% of current N, P, K consumption.

Return of animal manure: If all the nutrients from the current stocks of cattle, chicken, pig, and sheep manure were captured, they would yield an astounding 345 million tons of N, P, K annually—more than twice the world's current consumption. Using animal manure also improves soil structure and organic content and reduces fertiliser runoffs (by roughing up the ground).[183] Depending on its composition, animal manure can either be applied directly or after anaerobic digesting/composting.

Return of human waste: Human waste also contains significant amounts of N, P, K. If nutrients contained in the waste of the world's population were captured, they would amount to 41 million tonnes, representing 28% of the current N, P, K consumption. There are, however, several concerns regarding the use of human waste as fertiliser. The pharmaceuticals, heavy metals, and hormones it contains are harmful to human health and ecosystems. New technologies could facilitate recovery and ensure safety of the materials returned to the soil.

183 In Arkansas, research revealed a 55% reduction in phosphorus concentration in runoff seven days after surface application of poultry litter made up mainly of tocro fescue—a grass used for fodder—compared with a similar rate of inorganic phosphorus. A Wisconsin study demonstrated that surface-applied dairy slurry reduced total phosphorus loss from a tilled field because the manure reduced losses of particulate phosphorus. John Lory et al, Using manure as a fertilizer for crop production, 2006

FIGURE 25 **Regenerative agricultural practices greatly reduce soil losses and quality deterioration**
Example of wheat-maize rotation grown in Red Ferralsol[1] soil



1 These soils occur mainly under tropical climates, and cover extensive areas on flat, generally well-drained land. They are considered strongly weathered and associated with old geomorphic surfaces.

SOURCE: Castro (1991) as reported in FAQ Concepts and impacts of conservation available at http://www.fao.org/docrep/003/Y1730E/y1703e03.htm#P194_29413

A broad range of regenerative farming practices

Nutrient waste can be cut while maintaining productivity. According to the IFDC, two-thirds of the nitrogen applied as chemical fertiliser often remains unabsorbed by crops and becomes an environmental pollutant, either in the form of potent greenhouse gases or runoff that pollutes streams and lakes. Less than 30% of the phosphate mined to produce phosphorus fertiliser becomes part of the food chain as a result of inefficiencies in its production and use. There are several ways to use chemical fertilisers more effectively, allowing smaller doses, such as slow-release fertilisers or deep placement and precision agriculture. Improving the effectiveness of nutrient use does not just reduce pressure on the fertiliser supply; reduced runoffs also protect the environment against the formation of aquatic 'dead zones' overloaded with oxygen-depleting chemicals, encouraging algae to bloom where rivers run into the ocean. One successful example is the urea deep-placement (UDP) technology project in Bangladesh (2008/2009), which has delivered a 20% increase in crop yields and a 40% decrease in nitrogen losses. Farmers who used this technique had additional annual net returns of USD 188/ha and the higher rice production resulted in food security for an additional 4.2 million Bangladeshis. In 2008 Bangladesh was able to cut its urea import needs by 50,000 Mt, saving not only USD 22 million in fertiliser imports but also a further USD 14 million in government subsidies.[184] Similar practices to select more carefully and apply more precise quantities can also reduce pesticides. As James Lomax of UNEP's Sustainable Consumption and Production Branch summarises it: 'The aim is to use fewer "bad" agricultural inputs and to use the "good" inputs better'.

'Integrated farming systems' refers to integrating livestock and crop farming to make it easier to return nutrients to the soil. Crops and livestock interact to create a synergy that can go beyond using the 'waste' products from animals as fertiliser for crops. One example is the 'aigamo method'. Keeping ducks on rice paddies was rediscovered by the Japanese farmer Takao Furuno in 1989. The droppings from the ducks are a natural fertiliser, but the ducks also keep insects and weeds under control and their wading and paddling oxygenates the water and stirs up the soil. The concept has been refined to integrate the nitrogen-fixing fern Azolla, further reducing the need for fertiliser. Furuno's rice output is reportedly a third higher than that of his neighbours, who use pesticides,[185] and in 2011, the technique was successfully tested in Camargue in southern France.

Another example is 'pasture cropping'. This is a technique of growing crops symbiotically with existing pastures. The mix of shallow-rooted crops and deep-rooted perennial pastures results in reduced wind and water erosion, improved soil structure, fewer weeds, greater nutrient availability and increased levels of organic carbon in the soil. Measurements in the NSW Central Highlands of Australia show that in such a system organic soil carbon levels can double over a 10-year period, and many crops there are now being sown without any chemicals or fertilisers.

The application of integrated farming and other permaculture principles has a measurable impact on the preservation of natural capital in terms of reduced nutrient and soil carbon losses, and it typically improves water retention too (Figure 25).

184 IFDC (http://www.ifdc.org/Technologies/Fertilizer/Fertilizer_Deep_Placement_(UDP))

185 'Ducks replace paddy-field pesticides', The Guardian, 24 January, 2012

4. An economic opportunity worth billions
Continued

How consumers will win

The net benefits of a more circular economy are likely to be shared between companies and consumers. 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 would be double for virgin material, so we would have to sell at a much higher price'.[186] Yet the examples in this report indicate that the real consumer benefits go beyond the immediate price effect. Further advantages include improved utility and lower total cost of ownership.

Greater utility. The utility or benefit felt by consumers during consumption may be enhanced by the additional choice or quality that circular models provide. Consumer choice increases as producers deliver systems that allow the tailoring of products or services to better meet consumer needs. The digital world already provides many examples of customisation based on individual taste/requirements (from a range of offerings for men's dress shirts, build-your-own chocolate or energy bars and ice cream combos, to NIKEiD sneaker customisation and Songkick concert or Amazon product recommendations). As new circular technologies go mainstream, further opportunities will arise for fast-moving consumer products. One example is Essential Dynamics, a U.S. startup working on a 3D printer for pastry chefs. Researchers at Cornell University are developing further professional and at-home food applications for printers of this kind.

Rental models such as those discussed for apparel will provide consumers with a greater choice at the same or even lower prices. Similarly, the choice of soft drinks is dramatically increased via concentrate delivery systems such as Coca Cola's in-store Freestyle machine or Sodastream's in-home system.

Reuse and rental models also provide consumers with access to higher-quality experiences without trading up to higher-priced propositions. Beer drinkers are able to enjoy their beer from heavy glass bottles rather than aluminium cans or PET bottles.

Clothing rental models will require clothes that last, allowing consumers to wear the latest fashion without any sacrifice of quality or price.

Lower total cost of ownership. Coca-Cola's Mexican bottler, Femsa, exemplifies how consumers are likely to reap immediate price benefits from the circular economy: 'On average, a refillable package is priced 18% less than the same size non-refillable package'.[187] Similar savings will be available throughout the value chain as companies move to more reusable packaging. B&Q, Argos, and John Lewis in the U.K. have already moved towards reusable transit packaging for larger items. As this report has discussed, however, cost benefits to consumers will go beyond the initial outlay. In apparel, for example, fast-changing trends will no longer result in high costs of ownership for consumers: the rate of obsolescence will be greatly reduced as wardrobes will no longer be packed with barely worn, out-of-fashion items. Consumers will also benefit from circular models through the longer-term reduction of municipal waste disposal costs and—directly or indirectly—other environmental costs associated with the old linear system.

To realise these benefits, consumers, will of course need to embrace new models of consumption. However, the changes in behaviour associated with more circular models will be motivated by the desire for higher utility and lower prices. The changes do not require consumers to assign a higher-value to products just because they are 'circular', i.e., produced using circular business models. On a more crowded planet, greater consumer awareness of the issues laid out in Chapter 1 is important, but the circular business models we have explored in this report will not rely on consumers putting societal or environmental needs ahead of their own. These models will provide businesses, the economy as a whole, and the individual consumer with economic benefits first and foremost, while also ensuring a regenerative model of consumption for future generations.

186 Interview with Mark Sumner, 16 December 2011

187 WRAP, Refillable glass beverage container systems in the U.K., 2008

The shift has begun
Mainstreaming the circular economy

5

Proposing concrete steps for participants in the consumer goods industry and for the public sector to bring the circular economy into the mainstream.



5. The shift has begun
Mainstreaming the circular economy

The signs that the circular economy could transform the consumer sector are already apparent. But major change is required, and the linear world will continue to offer some powerful disincentives for incumbents to take action. This chapter examines how companies, consumers and public constituents can jointly accelerate the transition towards the new economy that we all ultimately need.

Why the time is now

Multiple factors are bringing about a change in attitudes and making the prospects of a circular economy more attractive. The growing scarcity of resources together with advances in technology and greater urbanisation are all heightening awareness that the time is ripe for change.

First, resource scarcity and tighter environmental standards are here to stay
Previous chapters have detailed the recent pressures on resource prices, and businesses already recognise the need to address sustainability and environmental standards. A 2011 McKinsey Quarterly executive survey revealed that the number of respondents pursuing sustainability initiatives to reduce costs or improve operating efficiency was up 70% over the previous year. The business case is increasingly clear. As a result, 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 previous year. Given their superior resource performance, it seems likely that investments in circular businesses will be systematically rewarded over those that espouse the 'take-make-dispose' principle.

Companies adopting a linear approach are also finding themselves subject to ever greater penalisation due to increased costs. Landfill costs, for instance, will rise in the UK from USD 107 per tonne today to USD 120 per tonne as of 1 April 2013, and are set to increase by USD 13 every year from then onwards. Fertilisers are another example. Their market prices increased by an average of 13.4% per annum from 2000 to 2011, reaching USD 147 per tonne. These (average) prices are also very volatile, as the 2008 spike of USD 399 per tonne of fertiliser showed.

Second, advanced technology is ushering in new opportunities to shift
Technology has progressed to a level that is opening up entirely new possibilities in three areas: information & communication, industrial applications, and online retail.

Information and communication technology has become a key enabler for facilitating circularity in consumer goods industries. New Information and communication technology is providing the huge benefit of access to a much broader spectrum of options and potential partners. Consumer goods industries generate discarded materials that may well have economic value, either as inputs in other sectors or even (reused or repurposed) within the same industry. This value, however, only materialises if an appropriate trading partner is found and—given the perishable nature of many by-products—if such a match is made sufficiently fast. The new opportunities provided by advanced information and communication technology are already being captured in some arenas. Marketplaces and auction platforms for trading waste and by-products—often with a regional or sectoral character—are a prime example. Distillers' dried grains are traded on the Chicago Mercantile Exchange platform. The Waste Producer Exchange (WPE) is an auction platform for individuals and companies willing to trade different types of waste in the south east of the UK (such as cardboard, paper, compost, food waste, liquids, oils, and other chemicals).

New *industrial technologies* are coming online or being deployed at scale, allowing more materials reuse and greater profitability.

- Technologies that facilitate collection and sorting: The use of RFID (radio frequency identification) has great capacity to boost materials reuse. For example, using RFID technology in the sorting of apparel and textiles at the end of their life enables the cascade of each type of textile to more suitable and higher value applications than is the case today. Wide adoption of RFID could be facilitated by falling technology prices.

• Technologies that facilitate reuse and recycling: 'Worn Again' is an example of recycling where technological innovation plays a critical role. It enables the separation of polyester and cotton followed by polyester recycling into new polyester, leaving the quality unaltered. Only 0.1% of materials are lost during processing. The cotton can be chemically recycled into cellulose and reintroduced to the textile value chain as viscose. This technology allows real closed-loop recycling of polyester and provides a solution to the industry-wide problem of blended fibres. In the food industry, Wildwood brewery has developed an integrated system to cascade or re-use materials. Beyond the actual brewing process, the operations of this Montana brewery include mycoculture, vermiculture, anaerobic digestion, aquaculture, and agriculture.

• Technologies that facilitate cascading: An innovator in the field of cascading use of waste to another value chain is Waste2Chemical, a bioengineering spin-off from Wageningen University in the Netherlands, where Professor Louise Vet fosters research and innovation around closed loop practices. This company develops bacteria that can process mixed waste and convert the different components (fats, proteins, and carbohydrates) into building blocks for the chemical industry. While still at lab stage, it has already attracted attention and collaboration opportunities from both municipal waste generators and the chemical industry. MBD Energy, mentioned above, has a further two projects under construction in Australia aimed at using algae to recycle captured industrial flue-gas emissions to produce liquid bio-fuels.

Online retailing provides a platform for new circular business models. In the U.S., online retailing amounted to USD 200 billion in 2011, making up 7% of the overall retail trade, and is expected to grow by a further 10.3% annually to USD 327 billion in 2016.[188] Over half of US consumers bought an item online in 2011. In emerging markets, where consumption is growing at breakneck pace (and, with it, the volumes of discarded materials and by-products), there has been swift uptake of the Internet and social networks. More than half of Internet users are in emerging markets. Brazilian social network penetration in 2010 was the second highest in the world, at 87.7%.[189] A recent McKinsey survey of urban African consumers in 15 cities across the continent found that almost 60% owned Internet-capable phones or smartphones.

Third, urbanisation is driving the centralisation of consumer goods flows
For the first time in history, over half of the world's population will reside in urban areas. By 2020, urban populations are expected to rise by a further 20% to over 4.2 billion, 80% of them in developing countries.

Centralised consumption should mean that reverse logistics—like the logistics of new product delivery—become more efficient and more cost-effective. The collection of household waste, as one example, will be cheaper due to shorter collection distances, and more efficient due to more frequent collection (increasing the collection rate and reducing waste leakage).

Integrated systems are an ideal solution to recover materials in urban areas, leveraging short transport distances and high population densities. Alterrus VertiCrop in Canada is another example. In the words of its CEO, VertiCrop technology represents 'a radical shift in sustainable food production.' Its vertical-farming patented technology uses hydroponic technology to grow leafy green vegetables and herbs in a greenhouse. The first rooftop incorporating this technology opened in November 2012 in Vancouver, with the aim of producing some 70 tons of leafy vegetables per year. The company targets yields up to 20 times higher than normal (field) production volumes, with fewer resources—only 8% of normal water consumption would be used, and no strong herbicides or pesticides. The vertical farms are much nearer urban centres, so they promote local sourcing and the supply of fresher food. The shorter transportation distances reduce costs, energy consumption and carbon footprint.

188 Forrester research and analysis

189 McKinsey Quarterly article, August 2012, : Winning the $30 trillion decathlon

5. The shift has begun
Continued

Some consumer goods companies are successfully pioneering circularity approaches

The concept and principles of the circular economy have already been put into practice with success by diverse companies across the consumer goods landscape. Prominent but diverse examples include Patagonia, ASOS, Uniqlo, and Sodastream.

Patagonia—Teaching clothing the 4 R's of waste reduction
Patagonia—a US-based USD 500 million (sales) maker of rugged outdoor clothing—is a long-standing advocate of sustainable materials usage through its 'Common Threads' initiatives. Having reached its initial goal of making all Patagonia® clothes recyclable, it has extended its efforts to tighter circles. Its website states: 'To wrest the full life out of every piece of our clothing, the first three of the famous four R's become equally important—to reduce, repair, and reuse, as well as recycle. We've also learned that we can't do it alone. We can only implement the four R's if we do it in partnership with our customers'.

First, Patagonia seeks to reduce the waste of clothing materials by making excellent clothing that lasts, so consumers can live comfortably with fewer pieces. The raw material should be organic, recycled or produced with minimal environmental and social harm. Committed to making clothes that last, stay reasonably in fashion, and serve as many uses as possible, Patagonia also explicitly calls on its customers 'to buy only what she or he will wear — and want to keep long enough to wear out'. Second: repair. Patagonia makes an effort to match the durability of all garment components so that one does not wear out while the remaining components and the garment as a whole still have a lot of life. If a zip fails prematurely, for example, Patagonia will carry out these repairs for free. Third: reuse. If a customer no longer wants a garment, Patagonia provides a way, through a third-party trading post, to sell it or donate it to someone. Fourth: recycle. As of July 2011, Patagonia publicly pledged to: 'take back for recycling any product ever made with a Patagonia label on it, including Patagonia Footwear (made under license by a separate company), and luggage and packs', and is willing to accept items for which the recycling or upcycling process is currently unclear or non-existent.

ASOS Marketplace—Reducing fast fashion's journey to landfill
ASOS—originally founded in the UK in June 2000 to make knockoffs of celebrity clothes ('As Seen On Screen')—is now a nearly USD 800 million fashion 'e-tailer' with 8.7 million registered users (June 2012). ASOS targets young fashion-minded women and men by offering more than 850 brands, including its own, served up with hip advice and trend-spotting. In 2010, as a complement to its site for new clothes, the company launched the online ASOS Marketplace 'where anyone, anywhere in the world, can sell fashion, to anyone, anywhere in the world'. By supporting the reuse of clothing, the Marketplace site helps to increase the time clothes spend in use without depriving consumers of their fashion consumption experience.

One of the UK's fastest growing retailers (with a CAGR of 142%) and its largest independent online fashion and beauty retailer, ASOS made the reuse of clothing an integral part of its strategy for building customer loyalty. ASOS founder and president Nick Robertson emphasises the business value of multiple 'customer touchpoints': 'Why do I allow customers to recycle their own wardrobes through Marketplace? Because the strategy is to engage with our core audience on a more emotional level rather than on just a functional 'shop and purchase' level'.[190]

Uniqlo—Maximising the durability of clothes
Like Patagonia, Japan-based Uniqlo ('Unique Clothing'), a company with revenues of USD 9 billion, is explicitly committed to making durable garments: 'Clothes should not be seen as disposable products'. Uniqlo's emphasis and motivation are customer centric yet span the world. Their mission is to provide clothing that meets the demands of every single person on the planet. As an apparel brand, Uniqlo believes that it is their duty to maximise the useful value of clothing. This is why Uniqlo refers to its clothes as 'shareable'. This concept also drives its All-Product Recycling Initiative. With its global partners UNHCR and JOICFP, Uniqlo has

190 The height of fashion. Marketing Week, June 2011

delivered 4.20 million pieces of clothing to refugees and others in need in 22 countries, including victims of the March 2011 disaster at Fukushima.

Sodastream—Making carbonated drinks at home

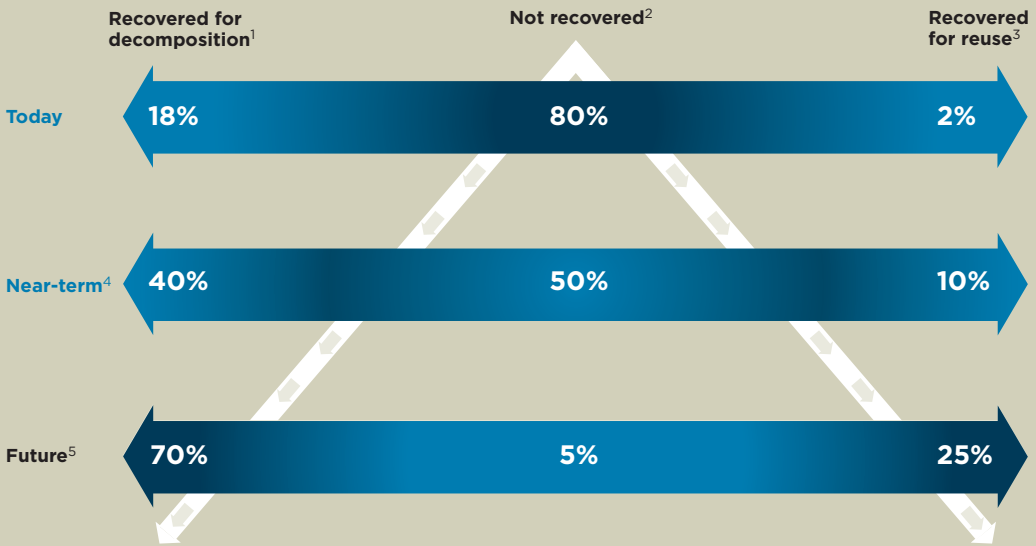
Israel-based Sodastream (2011 revenues of USD 275 million) is to carbonated drinks what Kindle is to books. Sodastream uses an established technology to displace consumable beverage packaging with a durable container. It has effectively created a revenue stream from both the sale of its apparatus and from a new consumable: the gas needed to infuse water and other beverages. Sodastream locks in customers through its system of refillable gas canisters as well as minimising the packaging material associated with gas consumption.

Which pattern of change?

Market innovators are probing new patterns of circular consumption. But their models remain the exception. What needs to happen for them to propagate? What will bring the manifesto of the European Resource Efficiency Platform (EREP) to life in its assertion that there is 'no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy'? Clear opportunities, set out in chapter 4, exist in the near term. Awareness and conviction are also on the rise. While it is too early to interpret these portents with precision, there are identifiable patterns of events and actors that have carried systems-level change towards the tipping point in the past. What change in economic pressure, shift in market share, or price fly-up will determine which patterns could usher in the circular economy at the critical scale required to reach the ideal future state[191] (Figure 30)?

Most typically, change has been a reaction to external shocks. Disruption of the global food supply would raise awareness of the need to shift to a more resilient model. Also, it is often in the wake of natural or man-made disasters that systems are (temporarily) rebuilt around resource security and much higher degrees of recovery.

FIGURE 30 **Path to a circular economy — design and recover consumer goods for reuse or decomposition**
% of FMCG products (by value)



1 Decomposition to allow materials to be recycled or biodegraded, depending on product/packaging material characteristics and end of life collection
2 Cannot be reused, recycled or biodegraded due to poor design and/or lack of end-of-life collection options
3 Reuse can include direct reuse for the same or different value streams or industries
3 Economic feasibility demonstrated in this report
4 Economic feasibility not yet proven

SOURCE: Euromonitor 2011, Expert interviews, Ellen MacArthur Foundation circular economy team

191 An ideal future-state split between materials recovered for decomposition and materials recovered for reuse has been estimated category by category; it considers the product design requirements shown in chapter 3, likely technical advances, and the ideal end-of-life collection systems that are matched to consumption patterns. Source: Expert interviews, Ellen MacArthur circular economy team

5. The shift has begun
Continued

Clearly, a *pervasive shift of consumer preferences* (such as seen towards instant food or bottled water) could drive the shift. As outlined above, early traces of that are becoming apparent.

A *'man on the moon'* program could provide pilot applications at critical scale. A plan to productively recover fertiliser or recycle CO_2 could act as a stimulus of this kind.

More recently, *killer applications* such as Google Earth have paved the way for fundamental change. This might involve offering a technological or data backbone, such as a materials passport that would allow designers and engineers to make well-informed design trade-offs when taking into account the entire life cycle of materials and products.

Or could change come as a *silent manufacturing* revolution in the way Toyota redefined the standard for good manufacturing? This might involve identifying and encouraging pioneers, or developing multiple success stories. Triggers to drive this revolution might be providing support to codify and spread knowledge, or establishing a culture of knowledge sharing. This would primarily entail a capability shift, and would need to be coupled with a strong profit incentive.

Perhaps the shift will come through a *voluntary, inclusive industry commitment* as witnessed in the food industry. An option could be to target supply chains where change seems attractive and attainable. All barriers to the circular economy would need exploring and addressing one by one. The key to success would be winning the commitment of players from different value chains. Creating forcing devices to ensure that supply chains collaborated (such as the EU's REACH model) would also nurture matchmaking opportunities. However, this alone is unlikely to provide the scale of adoption or degree of change required, as past efforts in other areas have shown.

History has seen all of these patterns lead to breakthrough: currently it is impossible to predict which of them will tip consumption into a more regenerative mode. We do know, however, that in the meanwhile the shift will be played out between pioneering industry leaders, discriminating, well-informed consumers, and forward-looking public constituencies. So what is the strategic case for these progressive companies and authorities to act now?

Buying the option—now

Clearly, shortening product lifecycles, untapped economies of scale, and the global division of labour will continue to be strong forces behind our global delivery systems and constitute a hard test for more localised and circular models. Yet in our interviews we consistently heard companies outline a picture of their industries in which circular models would be a defining competitive advantage. The target picture differs by industry, but they share similarities: being more localised in terms of delivery, more intimate in their customer relationships, and more appreciative of feedstock control.

Localised and integrated supply chains in the food industry

Many food companies we spoke to expect localisation and integration of supply chains to be crucial in many markets. Local inputs are becoming more common, with many companies also taking greater control of their supply chains, such as PepsiCo's decision to grow potatoes locally in China for its crisps and Nestlé's on-going local sourcing drive across developed and developing markets.[192]

Producers are deepening their service propositions by providing higher-value activities. Nestlé, for example, are expanding their premium offerings and associated services through their professional business. Companies are also taking more control over by-products and return flows of residuals. Gerber, the leading producer of fruit juices in the U.K., have implemented a dual-stream process. All juice that previously would have gone to waste is now either sent to community organisations, or, if unfit for consumption, to local recycling via an anaerobic digester.[193]

This will all contribute to the central 'circular economy mission' by reducing the volume of produce discarded by consumers, while also returning nutrients to the soil. It will also generate new revenue opportunities as

192 Financial Times, 'A market for local sourcing', 6 April, 2011; Nestle website 'Local manufacturing commitment' (http://www.nestle.com/csv/ruraldevelopment/impactsofourfactories/localmanufacturingcommitment)

193 Institute of Grocery Distribution website – 'Managing food surpluses responsible' (http://www.igd.com/our-expertise/Supply-chain/Sustainable-supply-chains/2661/Supply-Chain-Waste-Prevention-Guide-2012-from-factory-in-gate-to-till/Case-Studies/Waste-Management-case-study-Gerber-Managing-food-surpluses-responsibly/)

outlined above and elsewhere in this report.

Retailing to micro-markets and circular supply chain design

How do retailers see their future? Today they are confronted by consumers demanding higher quality at lower prices, while also expecting regionally produced food from big chains. Walmart, for example, increased sales of their locally sourced produce by 97% in 2011, to over 10% of total produce sold in the U.S.[194] Consumers judge supermarkets on their fresh products, yet the fresh chain is the most difficult of all to manage.

Circular principles that could help retailers master these challenges and meet consumers' needs would be to shorten the value chain, making local production possible. A number of examples already described in previous chapters exemplify how collaboration along the value chain can simplify processes while also reducing costs (and thus prices for consumers). Circularity also reduces overall exposure of the value chain to commodity inputs and opens up greater opportunities for using local farms as effective, collaborative suppliers. Discarded foods will serve as fertiliser and soil improvement for farms, or as a source of bio-based energy and chemicals; in return, farms will sell back quality local produce at competitive prices.

Apparel companies as fashion partners for life

Apparel and textile companies have always strived for longer-term relationships with their customers. In the circular economy, consumers would have fashion partners from whom they would select their apparel, returning it in exchange for new clothes. Products would be more tailored to consumer needs due to the greater interaction between producers and end users. The benefits for companies would be greater customer loyalty driven both by enhanced customer experience and the new ancillary services they offer (such as repairing garments and providing after-sales customisation). The recycling loop would close via smarter product design and breakthrough technologies that allowed high-quality textile reuse. The prime benefit for companies would be lower materials costs.

Cities and other public constituents as supply chain integrators and brokers of first resort

Companies—as we have seen—have a growing incentive to redesign products and chains vertically, starting from the top, to eradicate costly waste and provide a more tailored offering. Likewise, cities and regions could play a new role in a world where materials and energy security are returning to the regional, if not local, agenda. Scotland, the Dutch city of Rotterdam, and Tianjin, Miluo, and Taiyuan cities in China have started to build circular economies and provide all the infrastructure, services, and policy support needed to advance circularity. They envisage more energy recovery, higher land productivity, value creation through new reverse cycle business development, and employment creation. They see the circular economy as an accelerator for their economic agenda. Some are creating knowledge innovation clusters for the circular economy that will help to trigger exponential expansion in the field. Benchmarks could be developed for every (relevant) industry that pursued cascading rather than mere recycling. Infant industries might be convened (such as nano-packaging or smart textiles) to evolve circular systems before the industry is mature, when designs, manufacturing footprints, and distribution models are locked in. Another avenue might be defining a template for a sector labelling initiative and establishing a pilot in a pioneer industry, such as clothing. Generating an open-source materials database would also assist in driving the change, giving details of each material's function, performance, and economics. In the apparel industry, for example, the Sustainable Apparel Coalition is developing the Higg Index to measure and score its industry's products and operations. Setting up a component trading scheme could make another huge contribution.

Some companies are starting to develop full-fledged regional resource plans for primary/secondary resources. Others are generating benchmarks by sector and region to achieve the resource targets of such regional strategies as the EU Resource Plan. An effective driver of change might be to create a circular-economy-based competition for municipalities and industrial parks. Governments could convene and

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5. The shift has begun
Continued

support supply chain initiatives for specific archetypes, such as high-value, high-volume, and new supply chains. Taxation scenarios might also be investigated to determine the impact of a potential shift from labour to non-renewable taxation. The effects of circularity on EU growth could also be explored, as well as its potential impact on employment and the trade balance.

New framework on circular design

If circular industrial design is carried by strong trends and is supportive of corporate and regional strategies, what is needed is a much more diligent search for waste and leakage along and across supply chains. Whether for companies, industries, or regions, the search can be organised in a very structured way, similar to value stream mapping in the context of lean manufacturing; the framework brings together the cardinal points to study: the wasted resource flows, value creation potential, possible barriers, and execution—be it in-house or by a third party. This is illustrated below for the food processing industry.

What flows to go after? Regardless of scope, the search begins similarly by answering the questions, 'What wasted resource flows exist?' and 'Which flows should we pursue, or pursue first, based on value?' For the first question, likely flows should be mapped from beginning to end point and including information on size, quality, and change, i.e., how each flow will change over time (reflecting known plans and forecasts) or might change (by assessing sensitivities) regarding production growth, process changes, or changes in raw material quality. The mapping exercise should include any waste materials and by-products that are already finding a useful application today, since higher-value uses might be available.

What is the potential payoff? During or upon completion of the basic maps of material flows, the second step is to assess the potential for value creation. This information may be a current (market) value/tonne of material taken from known metrics for documented processes, some of which may already be commercially established (e.g., for oil trap grease) or a potential value/tonne based on analogous materials, requiring estimates. At a minimum, it is possible to identify the presence of key ingredients such as sugars, aromatics, polysaccharides, or oils. For each main family of ingredients, lists exist of the platform molecules that can be derived from them, and potentially of the chemicals and products that can be derived from these building block molecules. (e.g., the U.S. Department of Energy investigated 300 platform molecules that theoretically could be derived from sugar for their technical feasibility and commercial attractiveness). The tally for this part of the investigation yields the incremental gross value creation potential of the ingredients. For flows with a positive value, the next step is to investigate the cost of the process of extracting the valuable ingredients. In the absence of cost data, the gross value can be used to determine a 'budget' for recovering and bringing the ingredients to market, making it easier to form an opinion on whether such a process (including logistics) could be economically viable.

It is useful to complete the resource mapping exercise with information on how the environmental or social footprint of the company/industry/region will be modified (ideally, improved) when making use of the hitherto wasted resource flow.

What has so far prevented or could prevent the value from being realised? In estimating the cost or working out a budget, it is necessary to consider known or potential barriers to extracting the value. While the details will differ by the material or ingredient in question, the main categories of barriers to look at are: technical, infrastructural, commercial, and regulatory.

How should the value be extracted? Here, a major decision is to determine how to handle execution. The terms of reference will differ somewhat depending on whether the question of execution is being raised by a company, an industry (e.g., an industry association on behalf of its members), or by a 'region' involving one or more government agencies and levels. At the high level, however, the question can initially be broken down to two basic

choices: Is the resource flow is part of or of interest to the core business? If not, is there a third-party provider available or can one be created (as a shared service or via regulation)?

Assuming execution is to be by a company in-house, management must then answer the following questions (and an industry association or regulator analogously):

- Who should we partner with in our own value chain and in other value chains to cover our needs regarding in-house logistics, external logistics, processing, and marketing end products?

- Who else in the system can provide support in the short, medium, and long term? This can include local/regional/national authorities, universities and research institutions, and industry associations.

If the resource stream is not of interest to a specific company, the question to answer is which third-party provider to contract with. If no obvious third party exists, there may be a role for an industry association to help form a 'utility company' to extract the value, or modifications to regulations may be needed to bridge the market failure. In any case, both deep industry knowledge and excellent matchmaking skills are a must.

What could a continuous improvement process look like for a new circular flow?
In both in-house and third-party solutions, operations should aim for a steady state of continuous improvement in value creation and cost reduction. Value creation will focus on seeking higher-value applications for the same material flows (without ruling out waste avoidance) and valorising a broader set of material flows. Cost reduction efforts will typically focus on improvements in scale, logistics, and processes—both in how the waste stream is created (perhaps changing one step in production, cleaning, or collection could result in a more valuable waste stream) and in how the waste/by-product is processed to recover value. Organisations like the Institute for Food Research in the U.K., or, at the European level, ISEKI Food Association, a not-for-profit organisation gathering academia and professionals from the food sector, are putting considerable effort in increasing the number of available technologies for processing waste valorisation, broadening the application of existing and novel technologies, scaling up commercially established processes, and addressing any number of framing questions, such as food safety concerns and distribution challenges.

Of course, such a framework needs to be adapted in the practical case to reflect the different interests and horizons of the particular group undertaking an analysis, but identifying wasted resources is of interest regardless of the differences in perspective. While a regional government agency may well lack detailed knowledge of a given industry's potential resources, it may have an advantage in knowing (or having the option to know) the 'big picture' and what other relevant value chains exist and what steps are being taken that might be usefully designed into an integrated cycle.

We are all aware that the materials and energy leakage from today's supply chains is no longer economically viable, and cannot be maintained forever. As this shift takes on clearer contours, the value of a design paradigm such as that provided by the circular economy cannot be overrated. It provides clarity for the multitude of decision makers who jointly own today's complex industrial chains. It links economics and the environment and delivers actionable criteria and tools enabling all of us to be a better steward of our supply flows and—eventually—the planet.

Appendix

Objective

The objective of our material saving analysis was to assess the value of materials that can be saved at a global level by applying circular practices within several fast-moving consumer goods categories.

In our research, we studied 10 different consumer goods categories: Apparel, Beauty and Personal Care, Beverages, Consumer Health, Fresh Food, Home Care, Packaged Food, Pet Care, Tissues and Hygiene, and Tobacco.

Methodology

Cases analysed in depth

We have identified circular opportunities at different steps of the value chain, specifically in production, packaging, and consumption. For each category and for each of these value-chain steps, we have based our estimates of the global materials savings and other effects on in-depth analysis of the configurations presented as examples in Chapter 3:

Breweries for production
Beverage packaging
Food waste for consumption

The textiles category was modelled for the whole textile value chain, i.e., from production to consumption, due to its particularly differentiated set of opportunities for reuse.

Materials savings calculations

For each of the four cases, we defined and calculated a materials savings ratio as follows:
Materials savings ($)/Cost of materials inputs ($)

This ratio is an indicator of the impact on material flows of circular economy solutions. In order to build a realistic metric rather than a fictive ratio uncorrelated with business reality, **we calculated material savings based on circular practices, conditional on these practices being profitable.**

Scenarios

Both local factors and the status of implementation of circular practices can affect the materials savings ratios. Hence, we accounted for these differences and modelled **four different scenarios.**

The first three scenarios are status quo, transition scenario, and an advanced scenario. The fourth scenario was a fictitious fully linear model that shows the results of having no circular solutions at all.

The **status quo** corresponds to the current situation observed (information gathered through interviews and Ellen MacArthur circular team analysis).
The **transition scenario** represents an intermediate situation in which the activation of circular enablers has initiated.
The **advanced scenario** corresponds to a situation in which key circular enablers have been activated and circular practices are in place.

Geographies

We have defined materials savings as savings from the application of profitable circular practices. Our analysis has shown that this ratio would be affected by local factors such as labour costs, organisation / business structures and processes, and infrastructure already in place. To adjust for this, we have varied the savings ratio across three geographic regions: Canada and the U.S., Europe, and the other large economic regions (Asia, Africa, and South America).

Scale-up of findings

We have **scaled up the materials savings using the cost of materials inputs for each of the ten fast-moving consumer goods categories.** The costs of materials inputs were derived using end consumption data from Euromonitor for 2011 and the share of materials inputs (in terms of retail price of the products) for each category. These percentages of material input were obtained through interviews with experts for each of the ten consumer goods categories.

Scenarios for more collection and circular treatment rates

	Scenario[6]	End-of-life products Millions p.a.	Collected Percent	Reuse[1] Percent[4]	Recycle[2] Percent[4]	Cascade[3] Percent[4]	Components and business model, transition and advanced scenario
Food and beverages: households and retail[7]	Status quo	12	30	-	–	100	• Currently, 47% of municipalities collect; increase to 75% in transition and 100% in advanced scenario • Households assumed to separate 50% of food waste produced, rising to 70% (WRAP trials: up to 77%) • Assume 90% of waste separated by commercial food waste producers, as easier to achieve by regulation and paying directly for waste
	Transition	12	50	-	–	100	
	Advanced	12	75	-	–	100	
Food and beverages: production	Status quo	2.3	60	100	–	60	• Collection rates increased through better handling of brewer's spent grains (BSG) due to improved communication and cross-value-chain collaboration • Cascade rate is equal to collected rate due to full reuse of collected BSG in other value chains
	Transition	2.3	70	100	–	70	
	Advanced	2.3	100	100	–	100	
Clothing	Status quo	1.2[5]	65	73	7	16	• Collection rates increased due to increased collection schemes both on the kerbside using 'survival bags' and in retail stores (e.g., H&M, M&S) • Reuse currently maximised by reprocessors • Recycling increases with further development of chemical processes
	Transition	1.1[5]	75	73	9	13	
	Advanced	1.0[5]	90	73	12	10	
Packaging	Status quo	1.0	–	–	49-61	–	• Transition scenario assumes 50% of all beer in reusable glass bottles; advanced scenario assumes industry-wide collaboration for 100% adoption • Recycling rates assumed constant for all packaging types (e.g., PET, aluminium and glass) • Collection rates for reuse at 95% via deposit scheme
	Transition	0.8	95	50	49-61	–	
	Advanced	0.1	95	100	49-61	–	

1 Reuse refers to both domestic and exported reuse of products in their original form
2 Recycling: A process of recovering and converting materials into new products within the original value stream and industry
3 Cascade: A process of putting materials and components into different uses after end-of-life across different value streams and industries
4 Rates as % of products collected; add up to 100%
5 End-of-life clothing decreases between stages as takeup of clothing rental schemes increases from 0% to 15% to 30%, thereby decreasing annual new production and end-of-life clothing
6 The cases are based in different locations. Food and beverages (households): UK; Food and beverages (Production): Brazil; Clothing: UK; Packaging: UK
7 Waste from households, food service and restaurants, and retail/distribution

SOURCE: Ellen MacArthur Foundation circular economy team

Appendix
Continued

Adjustments to assumptions for net material cost savings calculations in different regions

	Changing variables	Europe	North America	Rest of World
Food and beverages: households and retail	Volume collected	• Status quo U.K. 30%, rising to 75%	• Status quo U.S. 2%, rising to 50%	• 12% rising to 30%
	Value	All materials values assumed to be the same globally (e.g., electricity, heat, fertiliser)		
Food and beverages: production	Volume	• Higher collection rate due to more efficient infrastructures	• Higher collection rate due to more efficient infrastructures	• Lower collection rate due to lack of infrastructure
	Value	All materials values assumed to be the same globally[1]		
Clothing	Volume	• Medium initial collection rate (25%) rising to 40% and 65%	• Low initial collection rate (15%) rising to 35% and 55% in transition and advanced scenarios • Chemical recycling increased from 0% to 9% in advanced scenario	• High initial collection rate (65%) rising to 75% and 90% in the transition and advanced scenarios • No chemical recycling
	Value	All materials values assumed to be the same globally (e.g., t-shirts, trousers)		
Packaging[2]	Volume	• 7% rising to 34% • Significant opportunities for reuse in some countries and for recycling in all	• 8% rising to 44% • Largest opportunity due to low base (reuse and recycling)	• 7% rising to 23% Reuse already prevalent driven by entrepreneurial sector; opportunities for recycling
	Value	All materials values assumed to be the same globally (e.g. glass, PET, alluminium)		

1 Relevant assumption only for the materials savings calculation. The value is derived based on the nutritive value of brewer's spent grains, minus discount for their wet state
2 Combination of reuse opportunities for beverage packaging and improved recycling opportunities due to better sorting for all other packaging

SOURCE: Ellen MacArthur Foundation circular economy team

Clothing: economics of circular business activities

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

	End-of-life optimisation USD per tonne of end-of-life clothing			**Rental** USD per renter		
	Status quo	Transition	Advanced	Status Quo	Transition	Advanced
Revenue	**1,973.89**	**1,938.89**	**1,909/34**	**1,009.69**	**1,009.69**	**1,009.69**
Treatment costs						
Buy-back/COGS	–	–	–	403.88	215.84	215.84
Collection and transportation	293.22	293.22	293.22	151.45	144.89	144.89
Pre-processing/sorting	332.10	332.10	332.10	–	–	–
Activity-specific process[2]	35.42	24.45	16.97	–	153.23	153.34
Other	21.23	21.23	21.23	282.71	282.71	282.71
Profit	**1,291.92**	**1,266.88**	**1,245.82**	**171.65**	**213.01**	**213.01**
Improvements in product design and reverse cycle skills	For rental • Decrease in cost of goods sold (COGS) due to reduced need to purchase clothing for each consumer • Decrease in delivery costs from introduction of delivery system to centralised lockers For end-of-life optimsation[1] • Decrease in revenues from shift in share of flows towards recycling • Decrease in processing costs from decreased flow towards wipers					

1 Describes conventional online retail model based on ownership
2 For end-of-life optimisation, includes cutting of fabric into wipers for portion of collected tonnage used as wipers. For rental, includes laundry charges.

SOURCE: WRAP, Valuing Our Clothes, 2012, WRAP, Textile flow and market development opportunities, 2012, expert interviews, Ellen MacArthur Foundation circular economy team

Appendix
Continued

Food and beverages production: economics of circular business activities[1]

Beer production by-product processing
USD per hectolitre of beer produced

	Status quo	Transition	Advanced
Revenue	1.14	1.56	2.00
Fish food	–	0.22	0.67
Livestock feed	1.11	1.33	1.33
Costs	0.09	0.13	0.09
Treatment costs	–	0.03	0.09
Landfill costs	0.20	0.10	–
Profit	0.94	1.43	1.927

Improvements in product design and reverse cycle skills

- Increase in revenues
  - Due to increased collection rate
  - Due to shift to more valuable applications
- Decreased costs due to avoided costs of landfill

1 From a brewery point of view

SOURCE: Euromonitor , Ellen MacArthur Foundation circular economy team analysis

Food and beverage consumption: economics of circular business activities

Food waste treatment with anaerobic digestion
USD per tonne of food waste

	Status quo	Transition	Advanced
Revenue from electricity, heat	43.82	43.82	43.82
Revenue from fertiliser	0	2.79	5.57
Revenue from feed-in tariff	63.87	63.87	63.87
Total revenue	107.69	110.48	113.26
Costs	63.43	53.45	43.46
Profit	39.87	53.536	69.80

Improvements in product design and reverse cycle skills

- An important parameter in the economics of an AD plant is the load factor, i.e., the time the plant is operational per year. We assume 95% availability for very good operations, compared to 90% on average
- If plants are rolled out on a large scale, operators can profit from price reductions of components through bulk ordering. We assume a total reduction by 25% in investment compared with median values found in the UK today
- Advances in the microbiology of AD could allow higher throughput, reducing investment by 25% overall General improvements in operational efficiency account for 15% reduction in operating cost compared with median values today
- Digestate is given away for free in the UK today. In the advanced scenario, we assume that digestate can be sold at the price of equivalent mineral fertiliser; however, this would require less expensive drying technologies to allow low-cost distribution and handling. In transition, a 50% discount versus the price of fertiliser is assumed

SOURCE: WRAP, NNFCC, Ellen MacArthur Foundation circular economy team

Appendix
Continued

Packaging: economics of circular business activities

Beer packaging reuse
USD per hectolitre of beer produced

	Status quo[2]	Transition	Advanced
Costs	**27.00**	**26.70**	**24.10**
Packaging	19.10	11.10	1.00
Transport	5.20	9.50	13.80
Processing and collection	2.80	3.80	4.50
In-store handling	–	0.80	1.50
Capital investment	–	1.70	3.30

Improvements in product design and reverse cycle skills

- Increase in revenues: no increase in volume sold or price paid has been assumed between packaging options
- Decreased costs
  - Due to high reuse rate (up to 30 cycles) facilitated by design of bottles for reuse (durability, anti-scuffing technologies, labelling to convey branding, etc.).
  - High collection rates facilitated by deposit scheme that provides incentive for return to collection point.
  - These processing and collection costs do not include the costs of collection for recycling and landfilling currently borne by the state in most markets, which would raise the savings for society from reusables.

1 For purposes of comparison, costs associated with packaging choice (e.g., materials costs, processing, transport, collection, in-store handling and capital requirements) are included. Revenues assumed to be equal for all packaging options, therefore not included in the analysis (since it is assumed that price and volume sold would not change based on packaging choice).
2 Status quo assumed to be current UK market split for beer packaging across glass, aluminium, and PET.

SOURCE: Expert interviews (SABMiller, Coca-Cola, WRAP), Recoup 2011 report, PwC : 'Reuse and Recycling Systems for Selected Beverage Packaging from a Sustainability Perspective', letsrecycle.com, Canadean 'Global beer trends 2012,' Ellen MacArthur Foundation circular economy team

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About The Ellen MacArthur Foundation

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

Thought leadership—The opportunity for a re-design revolution
The Foundation works to strengthen and communicate the ideas and opportunities around a circular economy, publishing a variety of materials (reports, case studies, educational resources...) as well as 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.

Relying on a network of international experts including key circular economy thinkers and leading academics, the Foundation strives to reinforce the framework's coherence as well as continue to develop it whilst making it available to key target audiences - educational institutions, business, and the public sector.

Business—Catalysing businesses innovation
Since its launch in September 2010 the Foundation has worked together with its Founding Partners (B&Q, BT/Cisco, National Grid and Renault) to embed circular economy thinking within four sectors of the economy.

The Foundation, with the support of the Founding Partners, has gone on to create a programme that focuses on building capacity across the wider business community. The Circular Economy 100 will provide the opportunity for 100 companies to stimulate circular economy innovation, foster collaboration, build capacity and unlock the economic opportunity through accelerator workshops, distance learning modules and an annual summit, hosted by the Foundation and its Founding Partners.

Education—Curriculum development and in-service teacher training
The Foundation works across secondary school and higher education, supporting critical and creative thinking around the circular economy. It relies on a portfolio of over 700 stimulus resources for learners and educators. Equally crucial is the Foundation's approach to learning and 'systems thinking'—the skill of understanding how individual activities interact within a bigger, interconnected world.

Secondary school programmes are lead by Development Field Officers working regionally across the UK. The higher education vision is of a global network of institutions that engage with the key ideas and priorities of the transition to a circular economy. Alongside this is an international masters-level Fellowship Programme featuring an annual summer school that will enable fellowship students to develop circular economy innovation projects within business, engineering and design disciplines. The Foundation has also developed two post-graduate courses including a PGCert in the circular economy and Innovation, Enterprise and Circular Economy MBA, both at Bradford University.



ELLEN MACARTHUR FOUNDATION
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