

All hands on deck for circular economy

The current and traditional linear extract-produce-use-and-dump material and energy flow model of the modern economic system is anything but sustainable. In a linear system companies make products and the consumers use and dispose. Thus, the material flow is understood as the conceptual logic of value creation, with only virgin material entering the flow. Such a linear production model incurs unnecessary resource losses in several ways: production chain and end-of-life waste, excessive energy use and erosion of ecosystems [Ellen MacArthur Foundation 2012; Michelini et al. 2017].

Throughout its evolution and diversification, our industrial economy has hardly moved beyond the linear model of resource consumption that was established in the early days of industrialisation. Companies harvest and extract essential ingredients, use them to manufacture products, and sell the products to consumers who discard them when they no longer serve their purpose. Granted, some major strides have been made to improve resource efficiency and explore new forms of energy. Nevertheless, a system based on consumption rather than on the restorative use of non-renewable resources entails significant losses of value and negative effects all along the material chain [Ellen MacArthur Foundation 2012].

Low resource prices relative to labour costs have generated a wasteful system of resource use. The largest economic efficiency gains have resulted from using more resources, especially energy, to reduce labour costs. In linear systems, the disposal of products in landfills means that all the residual energy is lost. Incineration or recycling of discarded products recoups a small part of the residual energy. Reuse, on the other hand, saves significantly more.

The erosion, over the past two centuries, of ecosystem services is often poorly understood. Ecosystems generate benefits that support and enhance human well-being. Forests, for example, absorb carbon dioxide and emit oxygen, add to soil carbon, regulate water tables, and deliver a host of other benefits. The Millennium Ecosystem Assessment (<https://www.millenniumassessment.org/en/About.html>) examined 24 ecosystem services, varying from direct services such as food provision to predominantly indirect services such as ecological control of pests and diseases. It appeared that 15 out of 24 services are being degraded or used unsustainably [Steffen et al. 2011]. In other words, humanity now consumes more than can sustainably be provided by the productivity of the Earth's ecosystems. As a result, the Earth's natural capital is actually being depleted. This simply cannot be allowed to go on.

The linear throughput flow model has dominated overall development causing serious environmental harm and, worse still, adverse effects on human and animal health. Unlike traditional recycling, the practical policy and business-orientated circular economy approach requires product, component and material reuse, remanufacturing, refurbishment, repair, cascading and upgrading [Rau & Oberhuber 2017; Borritz 2018]. Moreover, the approach needs to be able to rely on solar, wind, biomass as well as waste-derived energy utilization throughout the product value chain and cradle-to-cradle life cycle [McDonough & Braungart 2002; Rashid et al. 2013, Ellen MacArthur Foundation 2012; Korhonen et al. 2018]. The European Union (EU) has realised it has no choice but to implement a resource efficient

and ultimately regenerative circular economy and has now designated resource efficiency as one of the flagships of its Europe 2020 strategy [Tukker 2015].

*Insert — What are the main findings of the Millennium Ecosystem Assessment?
(more information available online on <https://www.millenniumassessment.org/en/About.html>)*

- 1. Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.*
- 2. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.*
- 3. The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals.*
- 4. The challenge of reversing the degradation of ecosystem while meeting increasing demands for services can be partially met under some scenarios considered by the MA, but will involve significant changes in policies, institutions and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.*

The circular economy concept is the trend and much lip service is paid to it these days. Kirchherr et al. [2017] have compiled a comprehensive set of 114 circular economy definitions and systematically analysed the definitions against a coding framework with a view to providing transparency in how the circular economy is currently understood. Their preferred definition reads: *A circular economy describes an economic system that is based on business models which replace the end-of-life concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.*

Also, the definition by the Ellen McArthur Foundation [2012] is often cited in recent publications. It reads: *“... an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.*

In their review of the circular economy, Ghisellini et al. [2016] point to the 4R approach, i.e. reduction, reuse, recycling and recovery, as being central to the circular economy. In actual fact, however, much of the policy has been geared towards promoting the third of the four components (recycling). Circular economy is most often considered as a form of more appropriate waste management. Such a limited

approach is headed for failure in as much as some recycling, reuse or recovery options may either not be appropriate in a given context, even though they may be in other situations, and that some conversion options may turn out to be much more expensive and damaging than conventional approaches that call for prevention rather than treatment.

Circular economy is seen as a new business model expected to lead to more sustainable development and a more harmonious society. Sustainable development requires a well-balanced and simultaneous scrutiny of the economic, environmental, technological and social aspects of an economy, sector or individual industrial process, not forgetting the interaction among all these aspects. Circular development has been defined in many ways, but the most frequently quoted definition comes from *Our Common Future*, also known as the Brundtland Report [1987]: *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

The circular economy is a positive contribution towards reconciling all the elements, thanks to its underlying rationale, mainly rooted in environmental and political [Birat 2015] as well as economic and business aspects [Ellen Macarthur Foundation 2012]. It promotes a more appropriate and environmentally sound use of resources aimed at the implementation of a greener economy, characterised by a new business model and innovative employment opportunities and by improved well-being and evident impacts on equity: *A world in which poverty is endemic will always be prone to ecological and other catastrophes* [Brundtland Report 1987].

The challenges that still lie ahead mean that fundamental principles must also be questioned. Can a regenerative model for instance emerge without any changes to fiscal policies? The importance of the impact the shift will have on commodity markets, coupled with the need to address unemployment (and immigration) in Europe, raises questions about the usefulness of continuing to tax labour rather than resources. Moreover, there seems to be an increasingly widespread view amongst European business leaders that our current economic models will not provide long-term prosperity in the context of global population growth and resource constraints.

The circular economy means rethinking and redesigning our future and there have been promising signs that a shift is now taking place. But reaching our goal will demand a pioneering sense of purpose if the ambitions are to be fulfilled with a system that is to rebuild our economic, social and natural capital. Efforts are required from all stakeholders, industries and industry federations, academics as well as policymakers. Builders will always experience more pleasure and satisfaction than spectators who stand on the sidelines complaining!

Within the context of circularity, plastics represent a key material. It goes without saying that a great deal of attention is paid to plastics, which does not mean that other materials should be neglected. The circular economy is an approach that will bring about considerable changes in numerous branches of the modern economy. It is therefore just as important for materials such as glass, metal, wood, paper and cardboard.

The world plastic production is forever on the increase. It has experienced an exponential growth over the past half century and the plastic market does not seem prepared to accept a setback, growing approximately 10 – 15 Mt every year. Unfortunately, there is no alignment between the rates of production increase and adequate results in still widely underperforming waste management [Geyer et al. 2017; Foschi & Bonoli 2019]. Some 6300 Mt of plastic waste were globally generated in 2015, of which ~9 % was recycled, ~12 % was incinerated and ~79 % was disposed of in landfills as well as in the natural environment. The world's oceans are still the main hub of mismanaged plastic waste. The largest plastics island, the so-called Great Pacific garbage patch, is located in the north central Pacific Ocean [Lebreton et al. 2018]. There is also a large accumulation zone of floating plastic debris in the Mediterranean Sea [Cózar et al. 2015].

A great deal of work still remains to be done. In 2016, ~17 Mt European plastic packaging waste was collected, of which merely ~41 % (less than half) was recycled [Plastics Europe 2017]. Waste traceability has become a priority for The European Commission. Accounting for 60 % of post-consumer plastic waste, plastic packaging is a main European concern: the recent Strategy for Plastics in a Circular Economy has set very ambitious goals for plastic packaging sustainability. In fact, the European Commission aims to achieve 100 % of reusable or easily recyclable plastic packaging placed on the market by 2030 [European Commission 2018]. It follows that the packaging industry has become the cornerstone of a broader vision of sustainable plastic value chain.

Also, Europe is determined to lead the struggle against plastic pollution. On January 18th, the European Union member states confirmed the provisional agreement reached between the presidency of the Council and the European Parliament on a new directive to introduce restrictions on certain single-use plastic products. In 2021, European citizens will say goodbye to plastic cutlery, plastic plates and plastic straws. These measures are closely related to the latest estimates on marine litter: according to the European Commission, plastics make up ~85 % of beach litter. Large plastic pieces injure, suffocate and often kill marine animals, including protected and endangered species. It is however micro-plastics that have reached record levels of concentration, threatening humans and other animals by entering the food chain. The market restriction of plastic cutlery and dishes is shifting manufacturing from virgin plastic to recycled, biodegradable and compostable plastic and alternative materials. Beverage bottles for example will contain 30 % recycled material by 2030. Other requirements are necessary to prevent (marine) littering. Not least citizen awareness, which plays a very important role in promoting responsible behaviour. The proposal for the *Directive on the Reduction of the Impact of Certain Plastic Products on the Environment* calls for collaboration among policy makers, industrial stakeholders, trade associations and consumers. Even if Member States have two years to transpose the Directive into national laws, it makes no sense to delay taking action. The sooner the better, initiatives need to be strengthened and disseminated on a broad European scale.

Given the huge amount of plastics used, bio-plastics may be a way of bringing the overwhelming waste problem under control. Hence, great efforts are needed to develop degradable biological materials without any environmental pollution to replace oil based traditional plastics [Nampoothiri et al. 2010].

Biodegradable materials are certainly eco-friendly, but there are a number of limitations such as the high cost of production and fairly poor mechanical properties. The decrease in fossil fuel availability because of increasing cost exacerbates the shortage of resources and promotes the need to create bio-plastic materials [Thakur et al. 2018]. Natural polymers and polymers from renewable resources could therefore provide an alternative to conventional plastics. Their use is advantageous, also from an economic point of view: their production generally requires less energy and does not result in the production of toxic by-products. The demand for bio-plastics is constantly growing, because they are applied in various contexts to manufacture ever more complex products. In 2017, the amount of biodegradable plastics produced at the global level was about 880 Gg, corresponding to less than 0.3 % of the total amount of plastics produced that year. The demand for bio-plastics is expected to grow to about 6 million tons per year (<https://www.european-bioplastics.org/>). To a large extent, this will also affect the packaging industry [Dobrucka 2019].

Aliphatic polyesters such as polylactide and polyhydroxyalkanoates have generated particular interest. Dobrucka [2019] describes the current bio-plastic market as well as some promising examples of the latest developments in bio-plastic packaging materials. Bio-plastics could be on the way to becoming an alternative to conventional packaging plastics.

Since the focus has shifted towards the creation of sustainable environment and the prevention of plastic waste disposal in both the terrestrial and aquatic environments, the production of bio-plastics has gained considerable attention. The main challenge however concerns the improvement of internal management to better meet the expectations (does anyone actually find a healthy world unimportant?). The necessary modification of internal management systems will have a substantial impact on supply chains, processes, marketing services and waste operations. Integrated skills and expertise are key to innovation and survival in the competitive market. The urgency and the size and complexity of the issue of sustainability mean that we will need all hands on deck. There is obviously only one basic requirement for an effective circular economy approach: efforts are required from all stakeholders, industries and industry federations, academics as well as policymakers. All are crucially important links in a chain and one missing link could cause the chain to snap.

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