# Integrated Waste Management

# Integrated Waste Management:

*The Circular Economy*

Edited by

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# CHAPTER ONE

# INTEGRATED WASTE MANAGEMENT: CIRCULARIZING THE ECONOMY FOR SUSTAINABLE DEVELOPMENT

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## Introduction

“Sustainability” is a business paradigm through which sustainable development strategies are being considered around the world. There is an increasingly popular mindset promoting the concept of corporate sustainability (Aggeri, 1999). Significant concerns that have come to the fore in the corporate sustainability space are the effects of environmental degradation and making industries and end-users accountable in the conventional system of production and consumption. The CONVENTIONAL production and consumption setup operates with a model that considers there to be unlimited resources available (*take*) in nature with which to *mak*e products or deliver services. There is also an endless sink in the ecosystem *to dispose* of used products, which are termed waste.

In light of this, one of the critical issues for humanity is how ever increasing waste is having ripple effects on the environment. According to the Global Waste Management Outlook (UNEP, 2015), the linear economy model is a critical driver of this phenomenon. It relies on the extraction of raw materials, turning them into finished products, and finally, the production of post-consumption waste. As such, there is a pressing need for a “green” paradigm in reinventing the production system, focusing on the ecological impacts of production and consumption and improving environmental footprints without compromising the economic bottom line (Garza-Reyes, 2015). This redesign of the production system should ensure economic sustainability and help achieve the “triple bottom line” of people, planet, and profit. Transformation of the way business is done needs to take place, contrary to the existing business paradigm of Take, Make, and Dispose (Waste).

## Waste or a Misplaced Resource

Pollution is increasingly becoming an index of any economic setup’s inefficiency and a symbol of wasted resources. Solid waste is a major concern with the current volume of waste produced annually estimated at about 11 billion tonnes/per year, giving a per capita solid waste generation rate of approximately 1.74 tonnes/year (Widmer, 2006; Seng et al., 2010; Sharholy et al., 2007; Álvaro et al., 2019; Deus et al., 2020). Based on current data, the Organisation for Economic Cooperation and Development (OECD) predicts that by 2020 waste production will have increased by more than 45 % compared to 1995.

*Solid waste management* is an externality created to serve the linear economy model. The production cycle, covering the stages of raw material extraction, manufacturing, sales, consumption, and disposal, has enormous environmental costs. In a conventional supply chain, resource depletion is witnessed at the upstream end thanks to society’s growing appetites with solid waste generation on the downstream side (Plaganyi et al., 2013; Sjöström and Östblom, 2010). Due to increasing concerns about the environmental impacts of industrialised society, it is increasingly recognized that there is a need to transition to a more sustainable socio-technical system (WBCSD, 2010; Seiffert and Loch, 2005).

Transformation of the current production and consumption system has to focus on adopting a concept of the value of waste, advocating the avoidance/reduction of waste generation in the first instance, and ensuring that residual waste is channeled towards conversion back into a resource (secondary) (Fudala-Ksiazek et al., 2016).

## Transformation of the Economic Structure and Business: From an Open to a Circular Economy

Contrary to the existing scenario, it is high time we envision Earth as a closed economic system, i.e. the economy and the environment are not shaped by linear flows, but by a closed system (Boulding, 1966). This model of an open-ended system needs to be converted into a circular system, considering the relationship between resource use and waste residuals. Thus, the circular economy model (CE) has emerged as a powerful strategy to deal with the growing menace of waste. The circular business model aims to couple commercial value creation by adopting resource efficiency strategies, such as zero waste, “cradle-to-cradle”, and biomimicry, leveraging the economic and environmental value of end-products.

New strategies are called for based on the concept of the circular economy. Businesses are the engine that can drive the transition required to achieve this. The transition to a circular economy is envisioned to play a central role in developing environmental approaches that measure, detect, and treat waste, as well as avoiding its production at source. This ensures that the end-product has an appropriate life-span with minimal environmental impact, decoupling economic growth from environmental degradation (Kirchherra et al., 2018).

This can be seen as a systems approach utilising the concepts of “industrial ecology”, “cradle-to-cradle”, “biomimicry”, and “natural capitalism”, also considered as potential principles of corporate sustainability. The concept of CE challenges the “take-make-waste (dispose of)” industrial paradigm, which has resulted in the reckless use of resources, leading to a massive increase in waste generation and environmental deterioration. It calls for a shift to the principles of the circular economy, in which material optimization should prevail in terms of resource productivity, and “reuse, recovery, and recycling” can yield eco-efficient products. The linear economy will gradually have to be replaced by a loop model encompassing sustainability principles (Cruz et al., 2012; Ghisellini et al., 2016). This approach refutes the thinking that endless resources are available for production cycles and unlimited sinks for waste generated in the industrial production-consumption process.

## The Circular Economy as a Business Model

The circular economy (CE) is emerging as a corporate sustainability strategy to optimize resource use at operational levels. The approach stresses reducing environmental externalities by redesigning and mimicking natural (ecosystem) models in the industrial system. This model can boost the waste value chain by encouraging eco-efficiency to help meet the environmental and economic bottom lines. This notion can be aligned to the business context of the triple bottom line (TBL) framework (Elkington, 1998), with the creation of sustainable enterprises that contribute to value creation and deliver economic, social, and environmental benefits. This is termed "the triple bottom line" (Elkington, 1998). The goal is an eco-efficient and sustainable production system.

On the one hand, there is a parallel push in business economics to reap payoffs like cost reductions and revenue generation, achieved through resource efficiency, optimization, and increased productivity. On the other, economic gains are realized through incremental innovation brought in by product or process improvements and product redesign, further contributing to competitiveness through resource optimization and productivity. This phenomenon is also leading to the eco-modernization of existing industrial clusters with a focus on pollution control technologies and stressing sustainability strategies like pollution prevention and product stewardship, as part of a vision to co-create a sustainable future. This will lead to new business models and opportunities, spawning skillsets for new jobs, and encouraging economic growth and social development (Fig. 1a, b. Circular economy model).

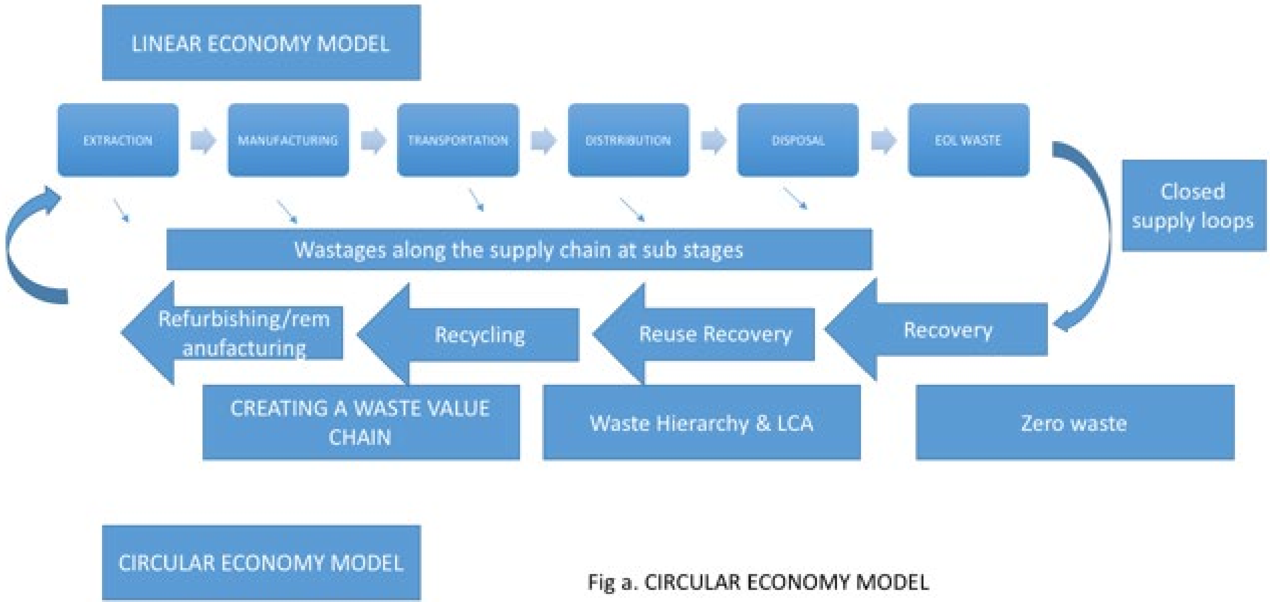


Fig. 1a. Circular economy model: production system.

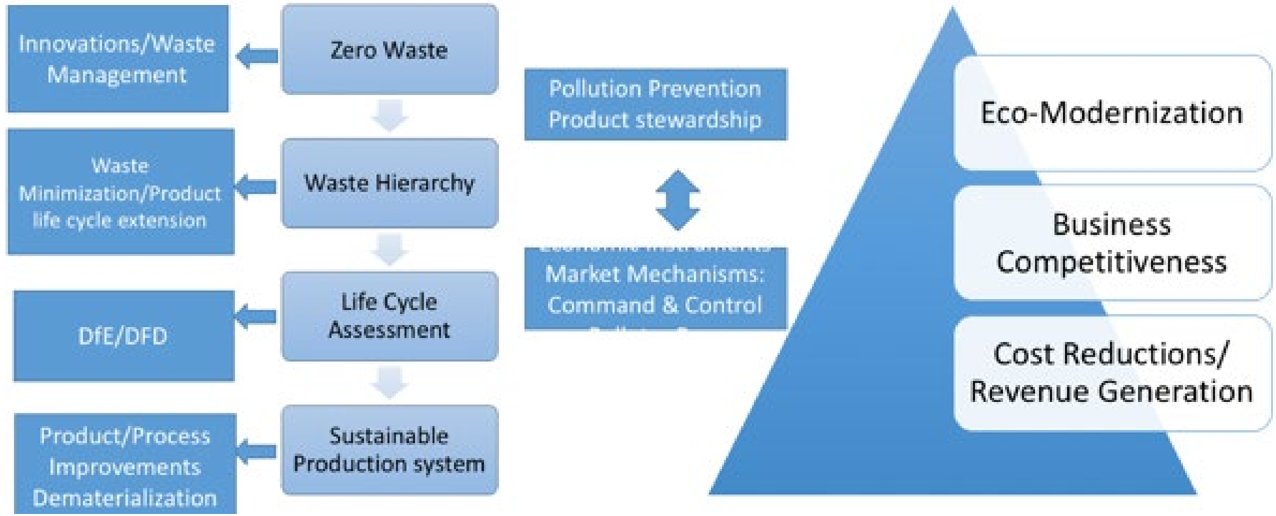


Fig. 1b. Circular economy model: business model.

# Theory and Principle

The concept of the circular economy (CE) relates to both the front and back ends of the industrial supply chain. It represents a plan for the entire life cycle of a product through resource extraction, manufacturing, distribution, consumption, and on to disposal. The approach focuses on designing environmentally safe products and services at the upstream of the supply chain and re-introducing waste (secondary resources) generated at each of these stages into the production cycle on the downstream side, either for reuse, recycling, and remanufacture, or end-of-life management (Montalvo, 2003; Lehmann 2010, Zaman and Lehmann, 2011; Strazza et al., 2015; Smol et al., 2015). This economic model of creating a reverse supply chain with a primary chain is based on the principles of "design for the environment" (DFE) and "design for disassembly" (DfD), advocating the "designing-out" of waste by easy deconstruction. It relies on efficient disassembly of used products (potential waste) so that they can be introduced into the supply chain for reuse, recycling, or refurbishment at the back end. It also calls for mimicking nature by introducing secondary raw materials in the reverse cycle for potential reuse. The concept also stresses increasing reliance on renewable energy for decreasing resource dependency, hence mitigating the challenge of constrained resource supplies by turning the one-way production system into a regenerative, self-sustained one. However, this requires the right mix of environmentally sound strategies, policies, and plans to effectively realize the concept (WEF, 2014; Murray et al., 2017). Thus, CE revolves around three interlinked concepts of:

i) life cycle management and assessment (LCA);
ii) solid waste hierarchy;
iii) and zero waste (ZW).

## *i) Life Cycle Assessment (LCA)*

Life cycle management and assessment (LCA) is a management philosophy that promotes life cycle thinking by mapping the entire value chain, product, and process to identify environmental impacts throughout a product's life cycle. It is increasingly being used to identify strategies that can improve systemic ecological performance by benchmarking various practices and technologies related to waste management. LCA can be used to evaluate alternative scenarios/environmental behaviour in relation to different waste streams emanating from MSW, C&D, and industrial, commercial, and agricultural waste. Studies in this area focus on analyzing impacts along the entire life cycle, with recycling, incineration, landfill, or other alternative treatments for various waste streams. LCA methodologies are applied to reduce waste generation, perform gap analysis, and, consequently, use wastes as byproducts, thus reducing running costs (Hertwich, 2005; Gmelin and Seuring, 2014). It aids in evaluating and quantifying the environmental impacts through indicators like global warming potential (GWP), ozone depletion, and eutrophication potential etc. The methodology involves identifying the study boundary and then creating a resource inventory (raw materials and energy) and an emission inventory, as well as identifying disposal pathways (Ceschin and Gaziulusoy, 2016; Beitzen-Heineke et al., 2017; Islam, 2017; Xanthos and Walker, 2017).

The model can be scaled up to the macro level with a focus on policy reforms, good governance, and planning to transform the behaviour of companies, encouraging them to bring in strategic changes at the organizational level (Farmer et al., 2015; Li et al., 2015; Permana et al., 2015; Warshawsky, 2015; Beitzen-Heineke et al., 2017; Islam, 2017; Xanthos and Walker, 2017).

### *ii) Hierarchy of Solid Wastes*

The concept of a waste hierarchy has gained wide popularity, prioritizing waste-management options into five steps: prevention, reuse, recycle, recovery, and disposal (Waste Framework Directive, 2008). Integration of the 5R principles into the production-consumption cycle is vital for effective CE implementation (Fig 2.). This concept counters the “end-of-the-pipe” approach to waste management and focuses on the development of an effective waste prevention strategy through waste reduction, reuse, or recycling, thus setting out the rationale for waste management at multiple tiers.

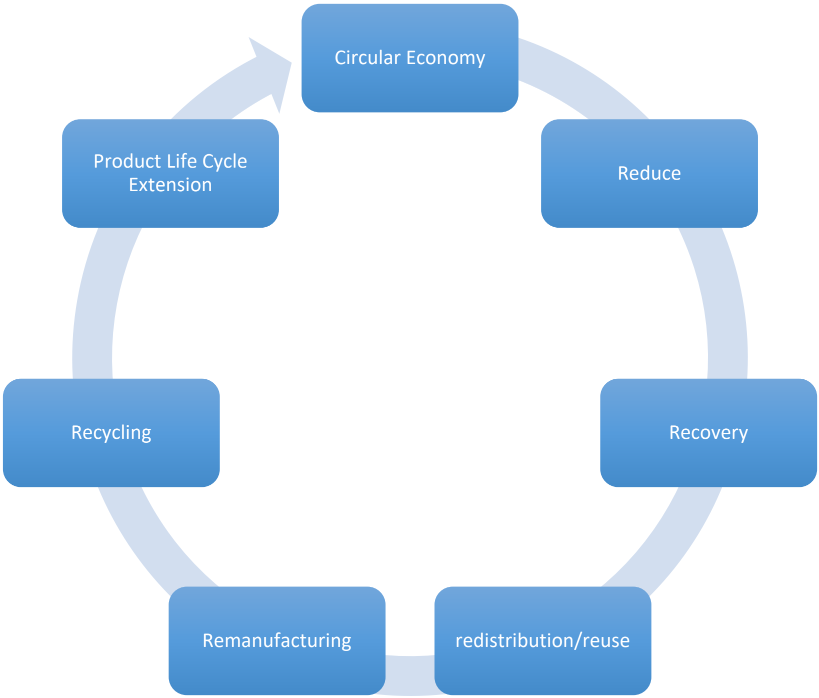


Fig. 2. Waste hierarchy in the CE model.

**Reduction** of resources through optimized resource use or reduced waste generation is a critical aspect of a circular economic system. Waste reduction can entail a change in the product mix or product design, or process improvements, leading to waste avoidance by advocating design for the environment (DfE) and design for disassembly (DfD). Reduction also refers to the minimization of inputs (raw materials and energy) through optimization techniques. In this way, waste reduction rather than waste disposal (landfill, incineration, dumping) offers revenue gains by reducing the cost of landfilling/transportation and end-of-the-pipe treatment/disposal activities.

**Reuse** involves channeling byproducts and wastes that have some recovery potential into the production cycle to be used as a secondary resource. The waste from one firm can be used as a resource in the same industry or other sectors, thus advancing the concept of industrial estates and exploiting the concept of symbiotic relationships. Industrial symbiosis is an effective strategy for reusing one industry's waste as a resource or raw material for another industry. It focuses on improving the functionality of a product and increasing its service life through maintenance or refurbishment.

**Recycling** involves processes for the recovery of materials and their breakdown and reformulation into new products to synchronize dematerialization in the business economy. Recycling can be aided by the production of end-products that are amenable to easy disassembly and recycling. This is achieved through the introduction of concepts like DfE and DfD (Wison, 2006).

**Remanufacturing** is defined as a multistep process to reconstruct a product with the same functionality that can then be introduced into the reverse supply chain to close the material loop.

On the business economics side, waste management according to the 5R principles helps reduce strain on resource streams. These principles reduce costs for firms and help bring in revenue by conserving raw materials and avoiding them becoming waste, rather than a product (Doonan et al., 2005). Simpson and Power (2005) demonstrated that proper waste management can reduce costs and enhance benefits giving a competitive advantage. Sustainable waste management provides incentives to stakeholders across the value chain by working on 3R strategies to minimize waste (Inter-American Development Bank, 2003).

On the environmental side, the focus is on the sustainable management of waste through the 5R principles with the goal of minimizing the quantity of waste going to landfill (Shekdar, 2009; Agamuthu and Fauziah, 2011; McBean et al., 1995; Neo, 2010; Achillas et al., 2011; Ahsan et al., 2012; Walls and Paquin, 2015). However, the success of this approach relies on looking beyond the production and technology spectrum, and encouraging stakeholder engagement and collaboration. There must be dialogue and cooperation between multiple entities across the industrial supply chain including manufacturers, suppliers, contractors, vendors, government institutions, and private businesses.

### *iii) Zero Waste Strategy*

"Zero waste (ZW)" is a broader than the waste hierarchy and life cycle assessment approach. A zero waste strategy goes beyond the 5R principles and calls for the redesign of industrial systems, product design, and industrial design to minimize waste from production systems (Connett and Sheehan, 2001, Gharfalkar et al., 2015; Ewijk and Stegemann, 2016). Zero waste sees waste as a mismanaged resource that can be put to use by better understanding of the product/process life cycle in addition to 5R. It focuses on 5R in an integrated fashion in terms of recycling and reusing products alongside restructuring and ecologically-focused design in the production and distribution cycle (UNECE, 2011). It builds on the concept of avoiding, reducing, reusing, redesigning, regenerating, recycling, repairing, remanufacturing, reselling, and redistributing waste resources.

Zero waste derives from the perception that waste must be understood as a potential resource that should be converted into secondary resources by targeting the back end of the manufacturing process (Dinshaw et al., 2006; Fudala-Ksiazek et al., 2016). It can operate at the upstream end of the supply chain by reducing the stress on the virgin resources through supplementing supplies. Secondary raw materials recovered by implementing the waste hierarchy model help in generating a significant economy in waste production per year (Zaman, 2015; Zaman, 2016; Zaman and Swapan, 2016). Zero waste entails designing and managing products in a scientific way to avoid waste generation and recovering waste products from all waste streams (ZWIA, 2013). It paves the way for product and process innovations, including design for the environment (DfE), which makes products amenable to easy disassembly and consequent recycling or remanufacturing (Mohan et al., 2016; Smol et al., 2016; Leo and Salvia, 2017).

This can lead to an industrial transformation and the creation of an industrial ecosystem that is self-sustaining, regenerative, and non-destructive, mimicking the natural cyclical system of degrading and replenishing resources.

The concept of zero waste has been implemented by many companies in many countries including South Africa, New Zealand, China, India, Canada, South Australia, and Taiwan (Greyson, 2007; Matete and Trois, 2008).

Zaman et al. (2011) proposed a tool called the Zero Waste Index (ZWI). This is a performance index to measure waste management efforts:

$$\mathrm{ZWI} = \frac{\sum_1^n \mathrm{WMS}_i \times \mathrm{SF}_i}{\sum_1^n \mathrm{GWS}}$$

Here, ZWI is the amount of waste avoided, recycled, and treated, etc.; WMSi is the potential amount of waste managed by the system; SFi is the substitution factor for different waste management systems based on their virgin material replacement efficiency; and GWS is the total amount of waste generated.

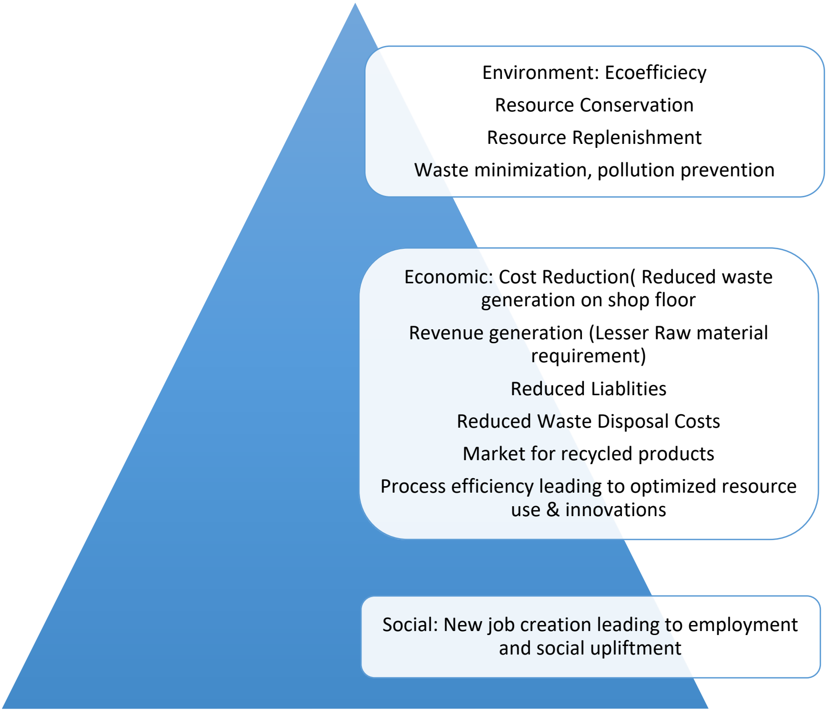


Fig. 3. CE model: meeting TBL.

The zero-waste concept has been instrumental in driving benefits in the economic, environmental, and social bottom lines. The *ecological benefits* accrue in waste prevention at the first level, followed by a reduced burden on environmental sinks like landfills and reduced stress on resources through resource optimization. The financial gains are seen in productivity improvements through increased resource efficiency from reuse, recycling, and redesign. Reduced costs, improved cash flows, revenue generation, and reduced liabilities (taxes and penalties) are all long-term economic incentives reaped from proper waste management practices. It has also been seen that waste management practices result in reducing risks to public health, improving lifestyles through altering consumption habits, and, in the long term, create job opportunities in the waste sector leading to improved livelihoods (Fig. 3).

## The Role of Economic Instruments in Waste Management

Many waste management STRATEGIES, like pollution prevention, waste minimization, or the introduction of circular processes, fail in terms of effective implementation due to financial unsustainability. There must be a balance between the economic sustainability of the proposed interventions and long-term environmental sustainability. To this end, a number of countries have developed a portfolio of instruments like “command and control” (CAC), the “polluter pays Principle” (PPP), and market-based instruments (also known as economic enstruments) to incentivize the proactive implementation of environmental measures and reduce the negative externalities of industrial growth. Economic instruments have been seen to help internalize externalities (Ščasný et al., 2009) besides reaping payoffs (Andersen et al., 2007). On the one hand, these mechanisms also help promote product environmental stewardship, improving incentive-based waste management programs.

## Command and Control Regulations (CAC)

Environmental issues have long been addressed with a mindset of damage control, rather than a damage prevention. Waste management using command and control (CAC) regulations makes the process compliance-centric by imposing penalties and fines. The standard strategy to tackle environmental problems has been through the command and control (CAC) approach, whereby regulations are imposed on polluters, and penalties are levied for the pollution load generated. However, this approach has turned environmental protection into a burden and an obligation to create a trade-off between environmental sustainability in relation to business sustainability.

## Market-based Instruments (MBI)

Recently, market-based instruments have been pushed as flexible mechanisms for coupling environmental and economic sustainability through waste management initiatives. Under this approach, incentives are created for corporates to take proactive measures that safeguard the environment, while penalties are imposed on those who fail to deliver

(Pearce and Turner, 1994; Inter-American Development Bank, 2003). The economic instruments employed include: product and input taxes; deposit/refund fees; advanced recycling fees; carbon taxes; and quantity-based collection charges. MBIs can help realize zero waste environmental strategies, the 5Rs, biomimicry, cradle-to-cradle, as well as many other tools like life cycle analysis (United Nations Environment Program, 2009ab).

The economic impetus of this approach provides incentives for a diverse pool of stakeholders across the value chain including producers, consumers, suppliers, and service providers (Inter-American Development Bank, 2003). This has led to a win-win situation contrary to the trade-off or obligatory mindset created by the command and control approach. Objectives like waste avoidance, waste minimization, and recycling can be successfully achieved through MBIs. These efforts encourage cost-effectiveness, economic efficiency, innovation, and eco-modernization.

## The Polluter Pays Principle (PPP)

The polluter pays principle (PPP) states that the polluter should pay. In solid waste management, the PPP implies that all waste generators are responsible for paying the costs associated with the waste they generate. This covers the costs of product use and disposal and calls for penalization for the externalities accrued during a product's life cycle.

One of the most recent ways of managing waste streams has been through the "extended policy responsibility" policy (EPR). The EPR policy builds on the polluter pays principle and is characterized by shifting responsibility from the government to various supply chain actors, predominantly producers. The extended producer responsibility policy (EPR) is a pollution prevention strategy that makes the producer responsible for product impacts in the take, make, and waste cycle.

### *Extended Producer Responsibility*

*Extended producer responsibility* (EPR) is a policy instrument widely adopted for prioritizing preventive measures over end-of-the-pipe pollution prevention approaches. It commands a transition from the conventional command and control approach to a more conducive market-driven approach. It defies the end-of-the-pipe treatment to comply with the environmental regulations based on penalties and taxes. EPR advocates incorporating incentive mechanisms for value chain stakeholders, particularly producers, to continuously improve their products and processes.

Extended producer responsibility (EPR) is a defining concept of the Basel Convention (UNEP, 2009a, b) and a method for integrating sustainable development principles based on the international environmental law principle known as the polluter pays principle (Kibert, 2004). EPR creates a financial mechanism for enforcing the circular economy concept, encompassing the zero waste strategy and the 5R principles. It ensures that products will be recycled by waste generators and refurbishers, with rippling impacts on the waste value chain. Changes include improving functionality in relation to environmental attributes like product recyclability and reusability, dematerialization, and other design for the environment (DfE) activities (Walls, 2006).

EPR is a policy tool aimed at preventing waste and developing a more product-oriented approach. It places responsibility for a product on the producer/generator. It works on the principle of product stewardship, whereby the producer still bears responsibility at the post-consumption stage. Thus, in line with the polluter pays principle, instead of placing the burden on the shoulders of local government and taxpayers, it argues for significantly more involvement of a new pair of actors—the producer and the consumer of a product.

EPR can be seen as a pollution prevention policy that focuses on product systems rather than production facilities. For the producer, this means that responsibility is extended from just considering the environmental impacts at the production facility to all those associated along the product's life cycle, particularly product consumption and end-of-life, thus mandating the role of LCA (Maxwell, 2001). Responding to environmental concerns, EPR makes use of the value chain concept and considers all the stakeholders, i.e. manufacturers, importers, and retailers, as being responsible for managing the product post end of life. This mandate, as a formal reverse supply chain that entails taking back/collecting and recovering EOL products, extends the producer's responsibility beyond the production stage and covers the EOL sub-stage. Thus, the environmental costs of the product are borne by internalizing the externalities and, in this way, the polluter pays for the ecological burden of the product.

The primary aim of the EPR policy is to combat pollution/the generation of waste and conserve natural resources. It is a PUSH strategy, motivating producers to innovate and develop products in harmony with the ecosystem that have limited impact (Maxwell, 2001; Krikke et al., 2003). EPR has become a valuable tool to engage the concepts of DFE and DFD, requiring an LCA of the product and fulfilling the objectives of the circular economy. This, in turn, informs practices of waste prevention through reduction, reuse, and recycling, besides internalizing the cost of environmental protection into product prices. Thus, it is a cost-effective instrument that encompasses all the possible avenues for waste reduction.

## Conclusion

The circular economy is a concept that can bring about a paradigm shift, harmonizing economic growth, environmental issues, resource scarcity, and social wellbeing. Strategies like developing a waste hierarchy, LCA, and zero waste need to be engaged at operational, tactical, and strategic levels. This will strengthen the concept of the triple bottom line and holistically encourage corporate sustainability. This mechanism to promote sustainable development has been taken up by EU members, BRICS countries, and many other national governments. It is time to realize the principles of the circular economy in practice through a focus on resource conservation, resource dematerialization, remanufacture, and redesign. All of these concepts must be embodied in industrial operations to bring about waste management at the meso, micro, and macro levels.

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# CHAPTER TWO

# CIRCULAR ECONOMY

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## Abstract

The circular economy has always been about maintaining the value of stocks, be they natural, human, cultural, financial, or manufactured capital, in a long-term perspective. It has evolved through three distinct phases, which today co-exist in parallel: a bioeconomy of natural materials ruled by Nature's circularity; an anthropogenic phase characterized by synthetic (man-made) materials and objects; and a phase of 'invisible' resources and immaterial constraints.

## Introduction

The objective of a circular economy is to maintain the value of stocks of different capitals over a long period of time, with a focus on the sustainable use or utilization of these stocks. In short, the circular economy is about stocks, not flows, and it is about waste prevention, not waste management (which is the final phase of the linear industrial economy, but somebody else's responsibility). Three phases can be distinguished, which exist in parallel:

**Circularity by Nature** has been the dominant principle since the beginning. Objects made of natural materials will decay without harming nature, or become food for other organisms—bacteria, insects, worms—at the end of their useful life. People are part of Nature's circularity. They lived within the limits of Nature until the Industrial Revolution extended society's limits beyond natural materials and individual skills.

In the **Anthropocene**, scientific progress opened a multitude of material opportunities in energy, metallurgy, and chemistry. These man-made materials are unknown to Nature's circularity. They therefore imply a man-made (producer) liability over their full life-cycle, constituting a mature circular industrial economy, which is about economics, innovation, and competitiveness.

A mature circular industrial economy is the third phase, characterized by **immaterial constraints** and '**invisible' resources**. It is based on a holistic understanding of circularity in sustainable development and includes liability, ethics, behavioral sciences, and accounting for the resources embodied in manufactured objects. New business models, such as sharing, require care and an understanding of cultural differences.

**The future** will see the borders between these three phases become increasingly fuzzy, with opportunities arising in new scientific, economic, and policy fields.

## Circularity by Nature

Most objects made of natural materials, like stone, timber, wool, and leather, will eventually decay without harming Nature, or become food for other organisms—bacteria, insects, worms—at the end of their useful life. Yet this circularity is limited by Nature's absorption capacity.

Nature is the physical world with no objectives, no monetary or time constraints, no ownership or liability. It is a system of zero waste, but not of zero carbon. Plants need $CO_2$ from the atmosphere to grow. This carbon is sequestrated in trees and remains embodied if the trees are harvested, and the timber is used for furniture or construction. The $CO_2$ will be released back into the atmosphere if the timber is incinerated or decays. Wildfires happen naturally and are beneficial to Nature in promoting resilient regrowth. However, where people are involved, wildfires may destroy economic capital.

Water and organic produce are supplied by Nature for individual consumption. Food once eaten cannot be resold; solar energy cannot be stored for later use. These resources are ruled by natural cycles and are therefore renewable, forming the 'bio-cycle'.