



**LAND MANAGEMENT, ENVIRONMENT & SOLID-WASTE:
INSIDE EDUCATION AND BUSINESS IN CENTRAL ASIA
ERASMUS-EDU-2023-CBHE Project Number: 101129032**

MICRO-CREDENTIAL

**CIRCULAR ECONOMY
FOR LAND AND WASTE MANAGEMENT**

**1.- Introduction to Circular Economy in Land and Waste
Systems**

***Foundations of Circular Economy
for Land and Waste Management
PDF W01***



Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

INDEX

1. SUMMARY OF KEY IDEAS	3
2. LEARNING OBJECTIVES.....	3
3. INTRODUCTION.....	3
4. THE CRISIS OF THE LINEAR ECONOMY	3
5. THE ANTHROPOGENIC MATERIAL LIFECYCLE	6
6. DEFINING THE CIRCULAR ECONOMY (CE)	7
6.1. Material Circularity: The Butterfly Diagram	9
6.2. Strategies for Circularity: The 10 Rs Hierarchy	10
6.3. Sustainability and Regional Challenges	10
7. CONCLUSIONS.....	11
8. REFERENCES.....	12

1. SUMMARY OF KEY IDEAS

Modern economies are based on intensive material extraction, transformation, consumption, and disposal. This linear model generates large waste streams, environmental degradation, and increasing pressure on land systems.

Understanding the drivers of material use, the anthropogenic material lifecycle, and the structure of waste management systems is essential for recognizing the limitations of linear systems.

The circular economy proposes a systemic transformation of production and consumption patterns by reducing resource input, extending product lifetimes, maintaining materials in use, and regenerating natural systems.

For land and waste management, circular economy principles are particularly important because land functions simultaneously as:

- A resource base (agriculture, mining, infrastructure),
- A spatial platform (urban development, industry),
- A sink for waste (landfills, tailings, dumping),
- A provider of ecosystem services.

The transition toward circularity is therefore linked to sustainable land management.

2. LEARNING OBJECTIVES

After finishing this lecture, students should be able to:

- Explain the main drivers of global material consumption.
- Describe the anthropogenic material lifecycle.
- Identify major types of waste and their environmental implications.
- Explain how waste management systems function.
- Analyse the structural limitations of the linear economy.
- Define circular economy and material circularity.
- Relate circular strategies to land and waste systems.

3. INTRODUCTION

Modern societies are fundamentally shaped by the extraction, transformation, circulation, and disposal of materials. Every building, road, electronic device, agricultural product, and item of packaging originates from natural resources that are removed from ecosystems and processed through complex industrial systems. Over the past century, global material use has expanded at an unprecedented scale, driven by

population growth, urbanisation, rising incomes, technological development, and changing consumption patterns. The expansion of cities, infrastructure, transportation systems, and industrial production has required vast quantities of biomass, fossil fuels, metals, and minerals. This increasing material throughput lies at the core of contemporary economic development, but it also generates mounting environmental pressure.

The relationship between population, affluence, and technological development helps explain why material use continues to grow. As populations expand and living standards rise, demand for goods and services increases. Technology can either intensify or reduce environmental impact, but in many cases, it has accelerated extraction and consumption. The cumulative result is a system characterised by high material throughput: resources are extracted from the earth, processed into products, consumed, and eventually discarded. This structure is commonly described as a linear economy.

The linear economic model follows a straightforward sequence: extraction, production, consumption, and disposal. Materials move in one direction, from natural ecosystems into the economy and finally back into the environment as waste. At each stage of this process, waste is generated. Mining operations produce tailings and overburden; manufacturing generates scrap and process residues; construction produces debris; households generate municipal solid waste; agriculture creates organic residues; and industrial activities produce hazardous by-products. Waste, therefore, is not an isolated or accidental phenomenon. It is embedded within the anthropogenic material lifecycle—the system of material flows created by human economic activity..

The anthropogenic material lifecycle begins with extraction. Raw materials are removed from forests, soils, rivers, and mineral deposits. These materials are then processed into intermediate goods and manufactured into final products. After distribution and use, products reach the end of their functional life. At that point, they may be reused, repaired, recycled, recovered for energy, or disposed of. In practice, a substantial proportion of materials ultimately end up in landfills or are released into the environment. Over time, materials accumulate in in-use stocks such as buildings, infrastructure, and durable goods. When these stocks are replaced or demolished, they become significant waste streams.

4. THE CRISIS OF THE LINEAR ECONOMY

The prevailing industrial model, established since the first industrial revolution, is a linear economy often described as a "take-make-throw" or "take-make-use-dispose" model. This system relies on extracting massive quantities of easily accessible resources and energy to produce goods that are used and then discarded as waste. Globally, this linear progression generates approximately 20 gigatonnes of waste annually, equivalent to roughly 7.5 kilograms per person per day.

This model is increasingly seen as unsustainable because it has reached the Planetary Boundaries—the environmental limits within which humanity can safely operate. Continued linear consumption leads to

the irreversible transformation of raw materials into waste, resulting in the depletion of natural resources, increased greenhouse gas emissions, and widespread pollution of air, water, and soil (Figure 1).

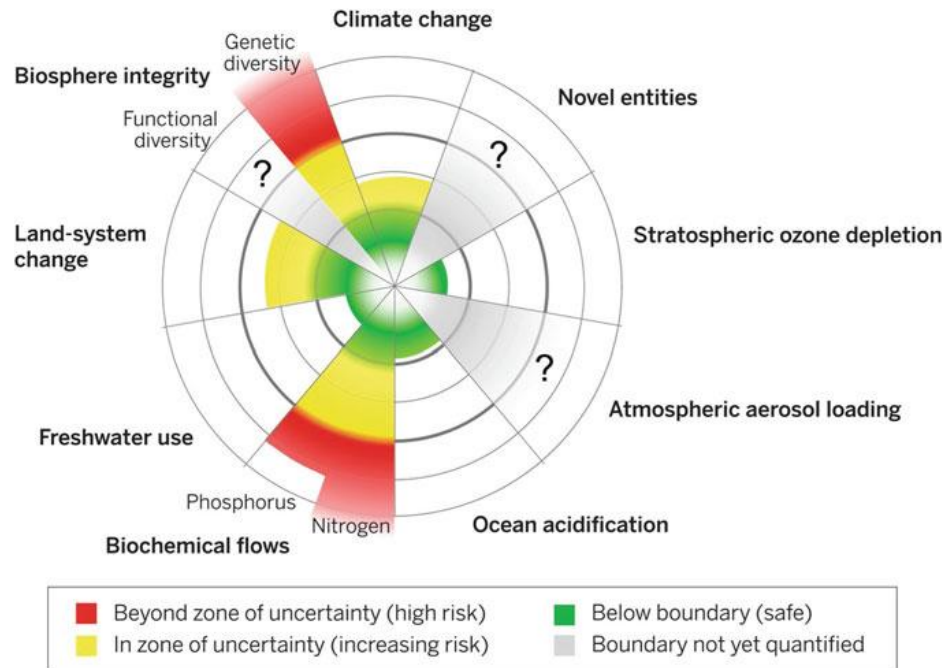


Figure 1. The planetary boundaries (M.Cui et al., 2023)

The Planetary Boundaries help us better understand where priorities need to be given in order to stay within these boundaries that support our lives on earth. The current state of the nine boundaries clearly calls for action and these actions need to be transformational. This is why the linear model that has brought unprecedented prosperity to mankind has to transition to a different model—a model that can help maintain the integrity of the earth systems that our prosperity relies on.



More than 90% of the raw materials extracted globally are not cycled back into the economy but become waste, emissions, or low-value outputs.

Only a small fraction of materials currently re-enter productive use through reuse, remanufacturing, or recycling.

5. THE ANTHROPOGENIC MATERIAL LIFECYCLE

To manage land and waste in a circular system, we must understand the anthropogenic material lifecycle, which describes the movement of materials through the "anthroposphere" (the part of the environment modified by humans). This cycle consists of five primary stages:

- Production: Extraction of primary feedstocks through mining, agriculture, forestry, or fishing.
- Manufacturing: Processing primary or secondary feedstocks into finished materials (e.g., steel) and products (e.g., cars).
- Use: The stage where products deliver their intended service, either as consumables (e.g., food) or durable goods (e.g., buildings).
- Treatment and Recovery: Activities to separate waste components, reduce their potential for harm, and recover material or energy value.
- Land Disposal: The final stage for materials not cycled back, typically involving storage in engineered landfills.

Cities are centers of human and economic activity. More than 50% of the global population lives in cities and they raise over 80% of global GDP [1]. They also consume 75% of natural resources, produce 50% of global waste, and 60–80% of greenhouse gas emissions [2]. Currently, major flows of material, energy, and water are taken from the environment, processed to value-added products, and delivered to cities, where their value is consumed and ultimately lost or discarded. In Europe, a region that is poor in primary resources, this open-ended linear flow has created a strong import dependency. The worldwide megatrends of urbanization, over-exploitation of resources, environmental degradation, and climate change call for an urgent transformation of cities from import-dependent, bottomless resource sinks into turntables capable of keeping valuable resources in continued reuse. In the next decades, 90% of urbanization will take place in the developing world [3], where an increase in living standards, in the current linear system, will result in a surge of resource consumption. By closing material, water and energy loops, cities can become resilient and succeed in providing decent, affordable living conditions in the long term while operating within the planetary boundaries; they should be decoupled from resource use and bad environmental impact. In fact, their specific attributes of cities make them inherently well equipped to model such a transformation. Urban centers have always been breeding grounds for new forms of societal and lifestyle concepts and offer ever-increasing room for innovation. Their immense human, economic, innovative, and resource capacity puts cities in the perfect position to drive forward the transformation toward a circular economy. Instead of resource sinks, cities could function as resource turntables, where products and materials stay in use.

In linear systems, materials enter cities—which act as resource sinks—and their value is destroyed upon disposal. Circular systems aim to transform these sinks into "turntables" that keep materials in continued use. (Figure 2).

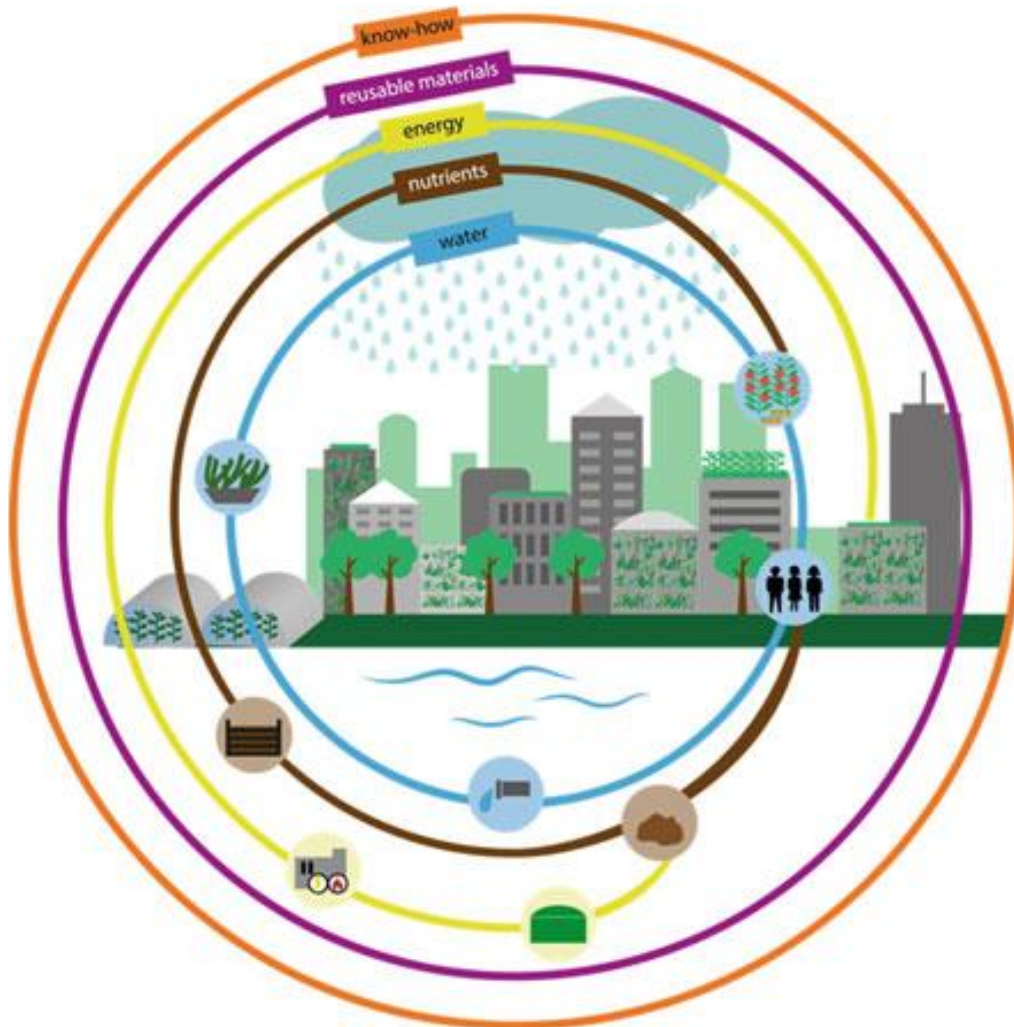


Figure 2. Circular city (<https://alchemy-nova.eu/>)

Cities are settlements with an urban center above 50,000 inhabitants [5]. A circular city is one that mitigates waste by keeping products, materials, and resources in use and regenerates natural systems. Nutrients are necessary for biological metabolism and are usually divided into macro- and micronutrients, as well as human and plant nutrients. Nature-based solutions are solutions that are 'inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more diverse, natural features, processes, and landscapes into cities, landscapes, and seascapes through locally adapted, resource-efficient, and systemic interventions [6]. Resource recovery means the recovery of materials from by-products or waste. In our understanding, it does not include energy recovery. Reuse in our context means using a certain material again, either for its original purpose or for a different function, without significantly decreasing its value

**Reflect**

Do you know how much waste is generated annually in your country, and what percentage of it is actually recycled or reused? Which material streams (for example, food waste, plastics, construction waste, agricultural residues) have the greatest circular potential in your region?

6. DEFINING THE CIRCULAR ECONOMY (CE)

A circular economy is an industrial system that is restorative and regenerative by intention and design. Its primary goal is to decouple economic growth from the consumption of finite resources and environmental degradation.

The CE framework is built on three core principles:

- Design out waste and pollution: Preventing waste from being created through superior design of materials, products, and systems.
- Keep products and materials in use: Maintaining products at their highest value for the longest possible time through reuse, repair, and remanufacturing.
- Regenerate natural systems: Moving beyond just "doing less harm" to rebuilding natural capital, such as soil health and biodiversity.

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. Moving away from today's linear model towards an economy that is regenerative by design is increasingly seen as required to meet the Sustainable Development Goals (SDGs) and tackle global environmental challenges. In such an economy, natural systems are regenerated, energy is from renewable sources, materials are safe and

increasingly from renewable sources and waste is avoided through superior design of materials, products and business models. A circular economy offers a positive way forward by redefining value creation to focus on society-wide benefits. It addresses the shortcomings of the current system, while creating new opportunities for businesses and society.

In short, a circular economy aims to decouple growth from the consumption of finite resources and build economic, natural and social capital. It is built on three principles: design out waste and pollution; keep products and materials in use; and regenerate natural systems (Figure 3). The circular economy framework distinguishes between technical and biological material cycles. In biological cycles, food and biologically-based materials—for example, cotton, wood—feedback into the system through composting or anaerobic digestion.



Figure 3. The 3 principles of the circular economy

These cycles regenerate living systems—for example, soil—which provide renewable resources for the economy. Technical cycles recover and restore products, components and materials through strategies including reuse, repair, remanufacture, refurbishment and in the last resort recycling. Digital technology has the power to support the transition to a circular economy by radically increasing virtualisation, dematerialisation, transparency and feedback-driven intelligence.



**Quick
Exercise**

Think of three products that you use regularly (for example, a plastic bottle, a smartphone, and a piece of clothing).

Can you identify what materials they are made of and what happens to them at the end of their life?

Make a simple diagram showing their material flow in a linear system. Then redraw the diagram showing how the flow could look in a circular system.

6.1. Material Circularity: The Butterfly Diagram

Circular thinking distinguishes between two types of material cycles, often illustrated by the "butterfly diagram" (Figure 4):

- **Biological Cycles (Biotic Nutrients):** These involve renewable materials, such as food and timber, that can naturally decompose and re-enter the biosphere safely to rebuild natural capital. In these cycles, "waste equals food" as the output of one process becomes the input for another.
- **Technical Cycles (Abiotic Nutrients):** These involve non-renewable materials like metals and plastics that do not decompose. These materials are designed to circulate at high quality within closed industrial loops through strategies like reuse, remanufacturing, and recycling without entering the environment.

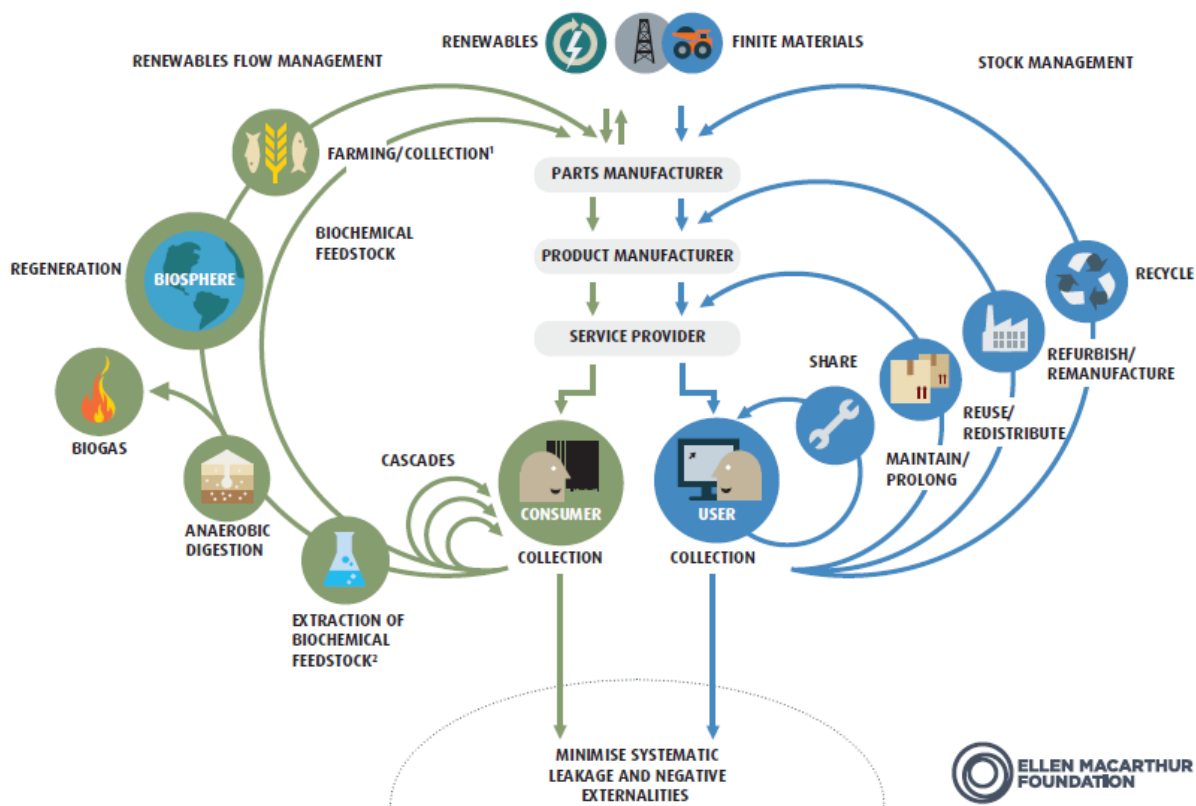


Figure 4. The "Butterfly diagram" of circular economy

6.2. Groundwater contamination

The circular economy expands the traditional "3 Rs" (Reduce, Reuse, Recycle) into a more detailed 10 Rs hierarchy to prioritize high-value material maintenance:

- Refuse: Abandon the function or offer a radical alternative to a product.
- Rethink: Make product use more intensive (e.g., sharing).
- Reduce: Increase efficiency in manufacture or use.
- Reuse: Re-use of a discarded product in good condition by another consumer.
- Repair: Maintenance and repair of defective products.
- Refurbish: Update an old product.
- Remanufacture: Use parts of a discarded product in a new product with the same function.
- Repurpose: Use a discarded product in a new product with a different function.
- Recycle: Process materials to obtain the same or lower quality.
- Recover: Incinerate material with energy recovery:

6.3. Sustainability and Regional Challenges

The transition to a circular economy is a key mechanism for achieving the UN 2030 Sustainable Development Goals (SDGs), particularly Goal 12 (Responsible Consumption and Production), which aims to halve global food waste and improve resource efficiency.

For Central Asian contexts (Kazakhstan and Uzbekistan), the transition faces unique structural constraints, including unequal access to digital infrastructure and the need for reconfiguration of higher education systems to include sustainability-oriented curricula. Successful implementation requires systems thinking, moving from individual product optimization to a holistic understanding of resource flows and trade-offs across the entire economy.



WARNING

Once valuable materials are dispersed through landfilling, uncontrolled dumping, or improper disposal, do you think it is easy to recover their original economic and environmental value?

In most cases, it is not. Material degradation, contamination, and energy losses make recovery costly and sometimes impossible. This highlights the importance of waste prevention, proper design, and early circular intervention rather than relying only on end-of-life solutions.

7. CONCLUSIONS

Understanding the foundations of circular economy for land and waste management begins with recognising the scale and structure of contemporary material use. Waste is not an isolated environmental problem but a systemic outcome of how the economy is organised. Waste management systems, while necessary, cannot alone resolve the inefficiencies embedded in linear production and consumption. Circular economy provides a framework for redesigning these systems to reduce throughput, retain value,

and regenerate natural resources. Because land is both a resource base and a sink for waste, the transition to circularity is inseparable from the pursuit of sustainable land management. By analysing material lifecycles and identifying opportunities to close loops, professionals in land and waste management can contribute to building more resource-efficient, resilient, and environmentally responsible systems.

8. REFERENCES

Ellen MacArthur Foundation (2013). Towards the Circular Economy.

European Commission (2020). Circular Economy Action Plan.

Food and Agriculture Organization of the United Nations (2015). Status of the World's Soil Resources.

United Nations Environment Programme (2021). Global Waste Management Outlook.

Circle Economy. (2023). The Circularity Gap Report 2023.

OECD. (2019). Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences.

European Environment Agency (EEA). (2020). Resource Efficiency and Circular Economy in Europe – Even More from Less.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.