Funded by the
Erasmus+ Programme
of the European Union

WOOD IN CIRCLE

Circular Economy – General Framework and Principles

Dipl. ing., Mg. oec. Janis Zvirgzdins

Researcher

Institute of Civil Engineering and Real Estate Economics

Riga Technical University

14.03.2022

VILNIUS TECH

1862 RIGA TECHNICAL UNIVERSITY

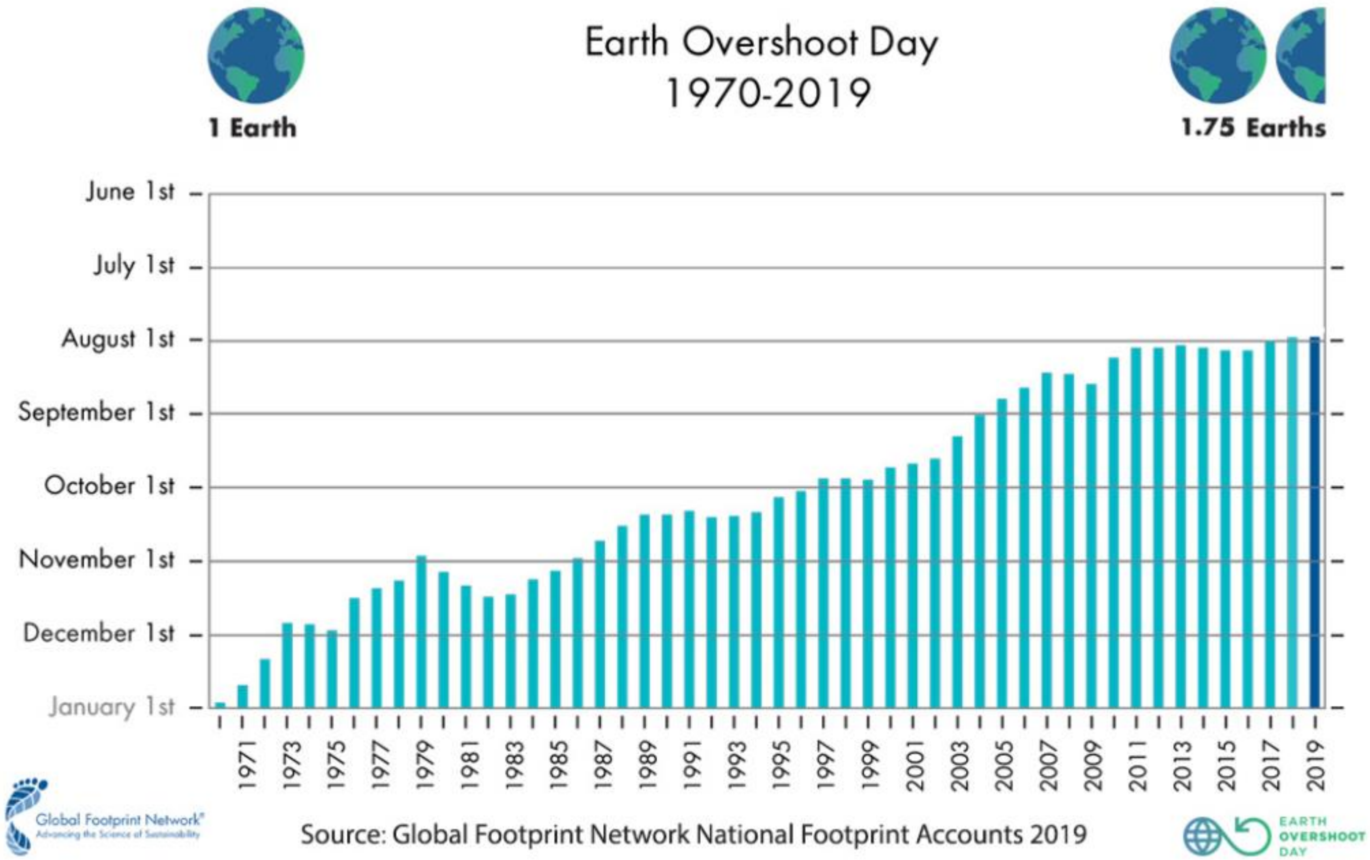
HAMK HÄMEEN AMMATTIKORKEAKOULU HÄME UNIVERSITY OF APPLIED SCIENCES

UNIVERSITÀ DEGLI STUDI DI PALERMO

LAUREA

Funded by the
Erasmus+ Programme
of the European Union

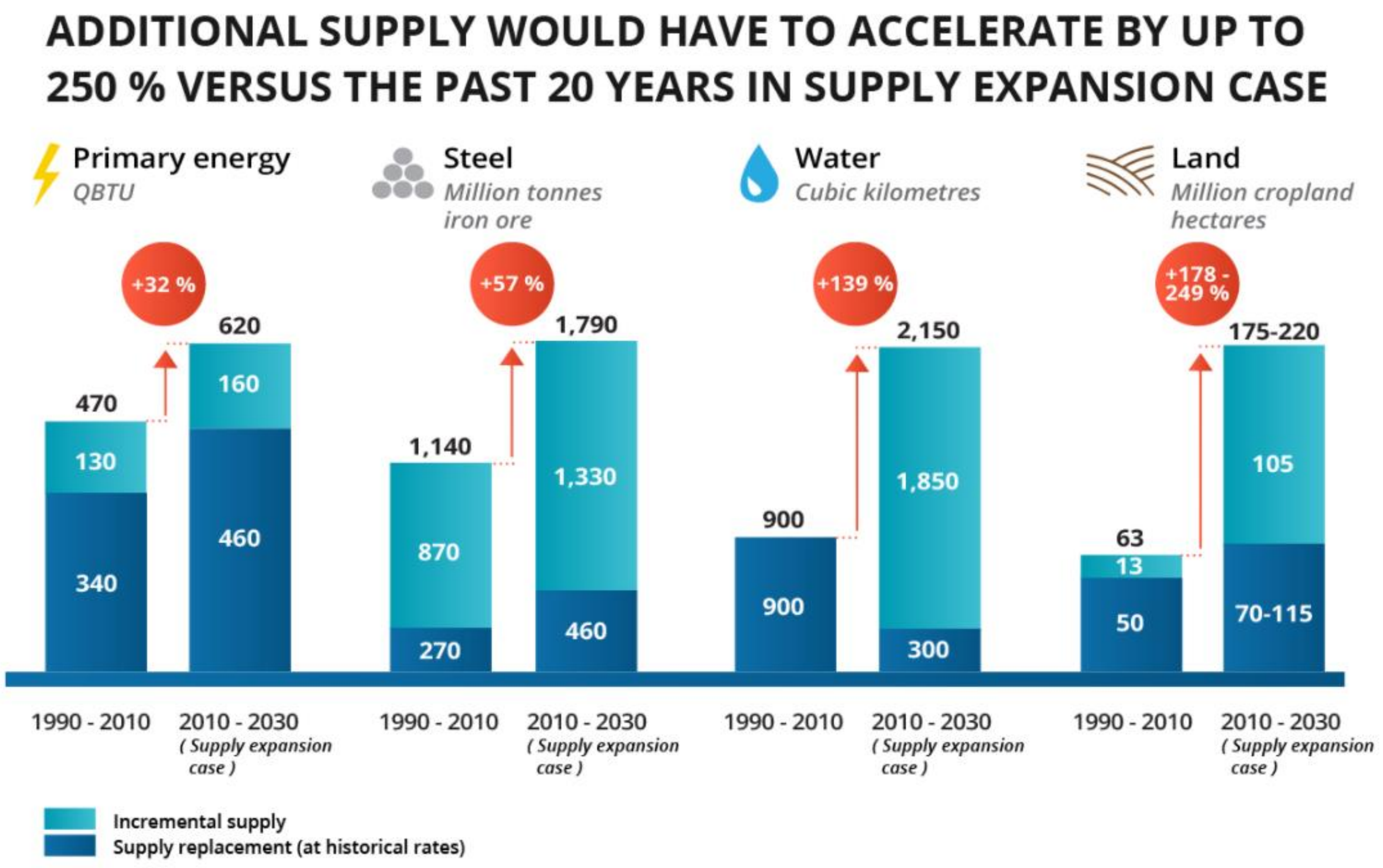
Earth Overshoot Day



Earth Overshoot Day falling on July 29th means that humanity is currently using nature 1.75 times faster than our planet's

Funded by the Erasmus+ Programme of the European Union

The growing need for resources in the coming decades



Funded by the Erasmus+ Programme of the European Union

Why is current situation escalating?

- The reason for the escalation of the situation is due to the current economic system.
- In the current **linear model** products are manufactured from virgin raw materials and after use the products and the materials tied up in them end up as waste. The system is based on the **extensive use of accessible and affordable materials and energy**, and is unable to meet the challenge of sustainable development.
- In order to ensure **sustainability**, economic growth should be decoupled from the unsustainable use of natural resources and damaging environmental effects. This requires extensive changes to the economic system and current operating models.

Funded by the Erasmus+ Programme of the European Union

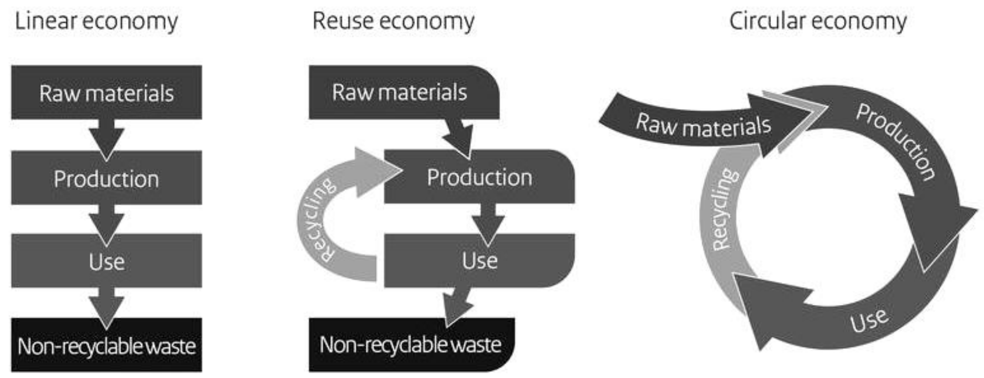
Circular economy

- Kenneth E. Boulding – 1966
- ‘cowboy’ economy (endless resources and the ability to move on and abandon problems) → ‘spaceship economy’, where limited resources had to be reused and recycled as a precondition to sustainable life support systems

Funded by the Erasmus+ Programme of the European Union

Comparison of economies

- In order to manage overconsumption and environmental problems, more sustainable ways of operating must be found that can replace the **take-make-use-dispose model**. In the **linear economic model** there is a continual need for new raw materials and after use, the materials are no longer available for further use. In the **reuse economy**, part of the materials used are transferred back to become the raw materials for new products, but in this case too, a large proportion are removed from the cycle as they become waste and new raw materials are continuously needed. Recycling, which is easily confused with the circular economy, focuses on finding uses for waste already generated. **The circular economy**, on the other hand, means an economy where the use of resources is designed for sustainability, so that materials and products circulate and are not used up. The circular economy tries to completely avoid the creation of waste, recycles products and materials, as well as minimises the use of new **resources**.



Funded by the Erasmus+ Programme of the European Union

What is Circular Economy?

- The circular economy is a new model for the economy in which **materials are recycled** and **added value** is created for products through services and creativity.
- The circular economy responds to the largest global challenges such as **climate change**, **depletion of natural resources**, and **loss of biodiversity**. Achieving circular economy objectives requires, however, new kinds of thinking and operating models, diverse expertise and a reorientation of business activities. In particular, different kinds of professionals are needed who can solve the difficult problems related to circular economy implementation.

Funded by the Erasmus+ Programme of the European Union

Circular economy - definitions

1. "Circular economy (CE) is a closed loop material flow in the whole economic system in association with the so called 3R principles (reduce, reuse, recycle). Taking into account economic aspects CE minimizes material use without restricting economic growth"(Lieder, M., & Rashid, A., 2016)
2. "CE is a mode of economic development that requires compliance with ecological laws. It is, essentially, an ecological economy that follows the principles of "reducing resource use, reusing, and recycling" (Zhijun, F., & Nailing, Y. (2007)
3. "CE is an industrial economy that is restorative or regenerative by intention and design" (MacArthur, E., 2013).
4. The circular economy keeps raw materials and materials in economic use for as long as possible using efficient cycles, so that the value of the material is maintained from one cycle to the next, and the environmental impacts of the use of materials is minimised. (Seppälä et al. 2016)
5. "The core of CE are the '3R' principles—reduction, reuse, and recycling of materials and energy. The approach is expected to achieve an efficient economy while discharging fewer pollutants. The strategy requires complete reform of the whole system of human activity" (Yuan, Z., Bi, J., & Moriguichi, 2006).
6. "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." (Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.)

Funded by the Erasmus+ Programme of the European Union

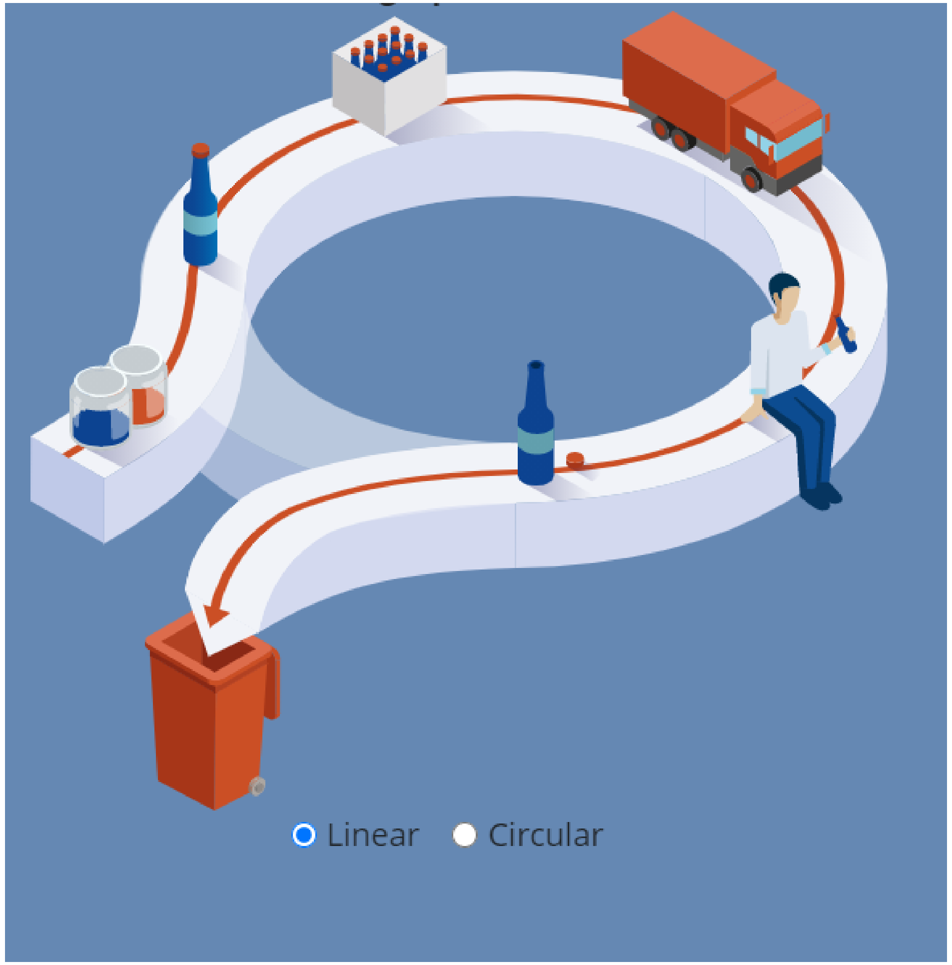
WOOD IN CIRCLE

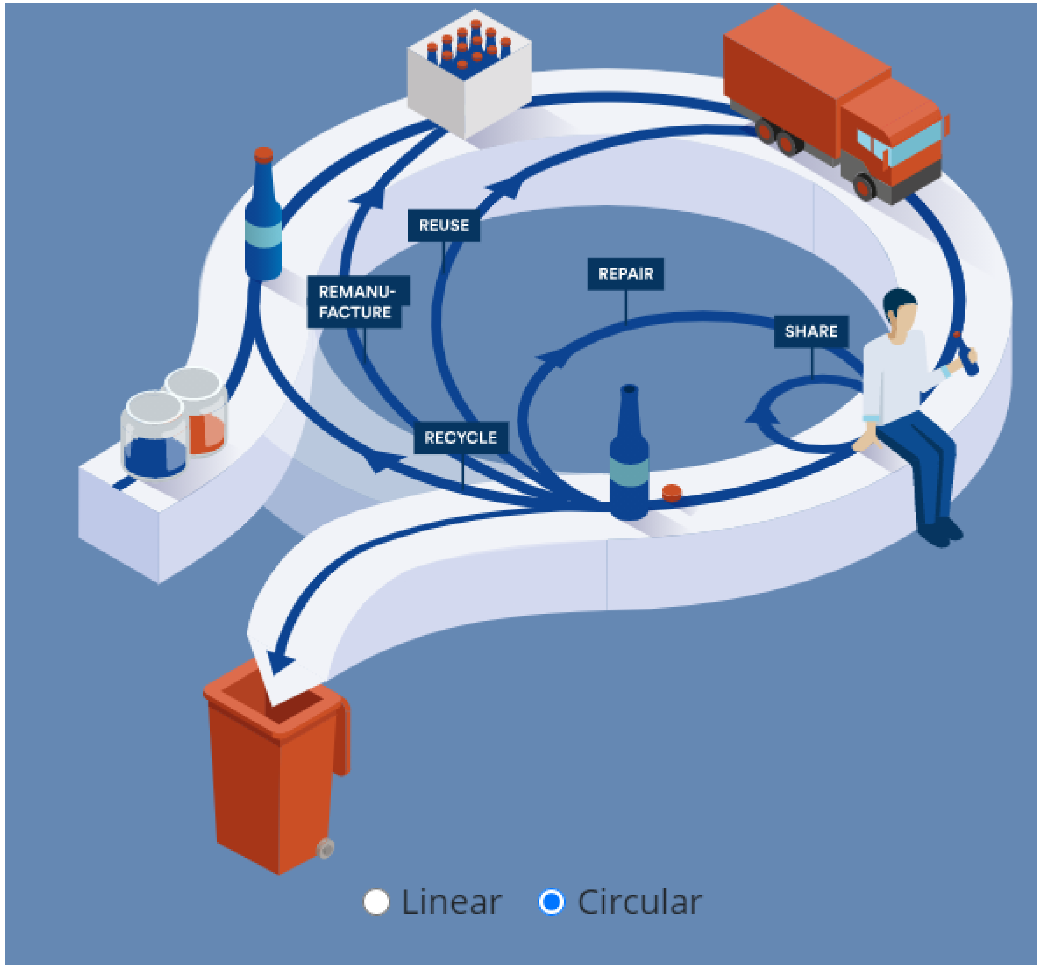
Why is the Circular Economy more important than ever?

- Because we need efficient methods for managing the challenges related to our planet’s explosive **population growth**, **diminishing natural resources** and **climate crisis**. With the help of the circular economy, we can use new operating models to create a sustainable way of living and acting on our home planet.

Funded by the Erasmus+ Programme of the European Union

Linear vs. Circular

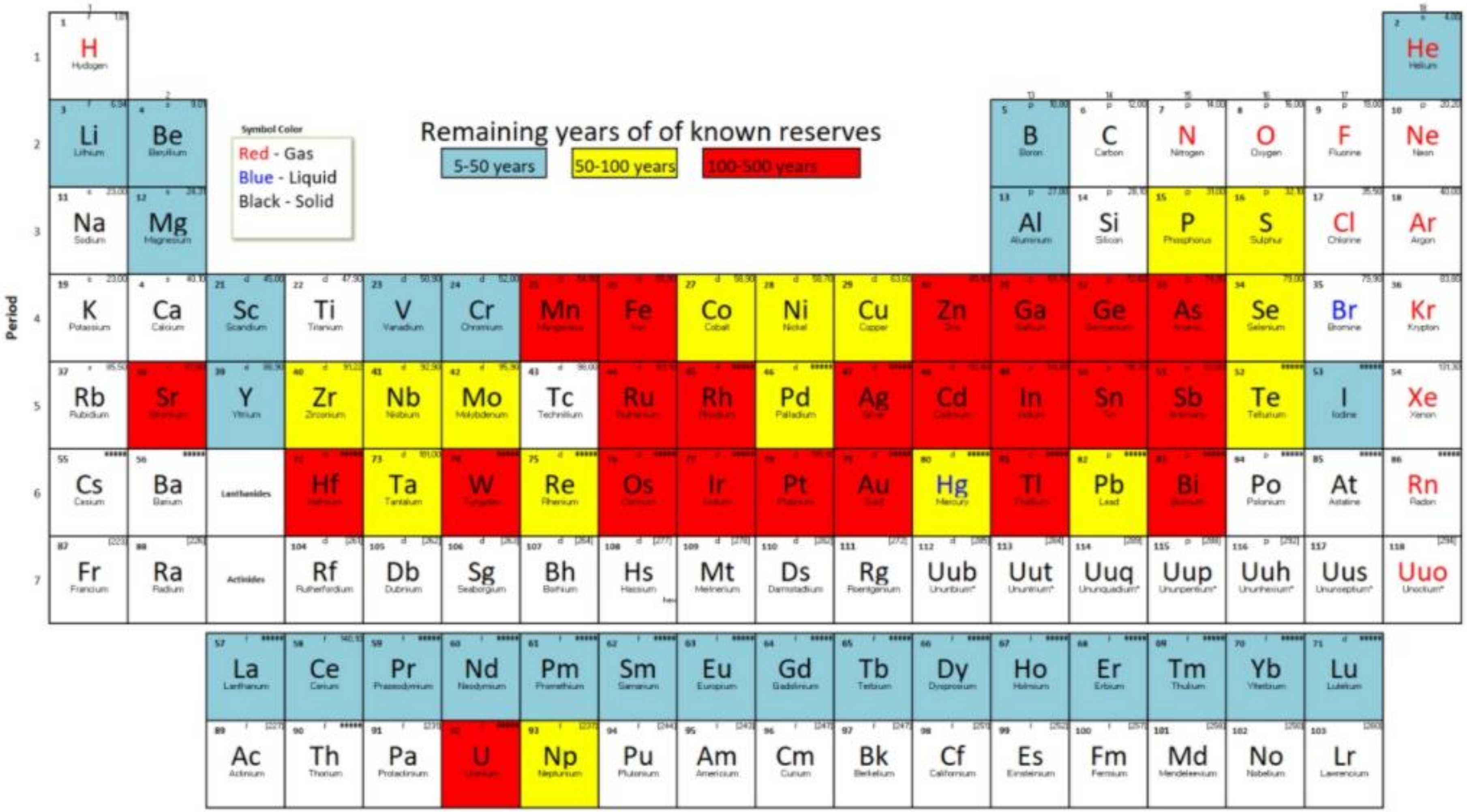




Source: https://ec.europa.eu/eurostat/cache/infographs/circulareconomy/

Funded by the Erasmus+ Programme of the European Union

Sufficiency of known reserves of rare and valuable metals if consumption continues as at present (Hunt et al. 2013)

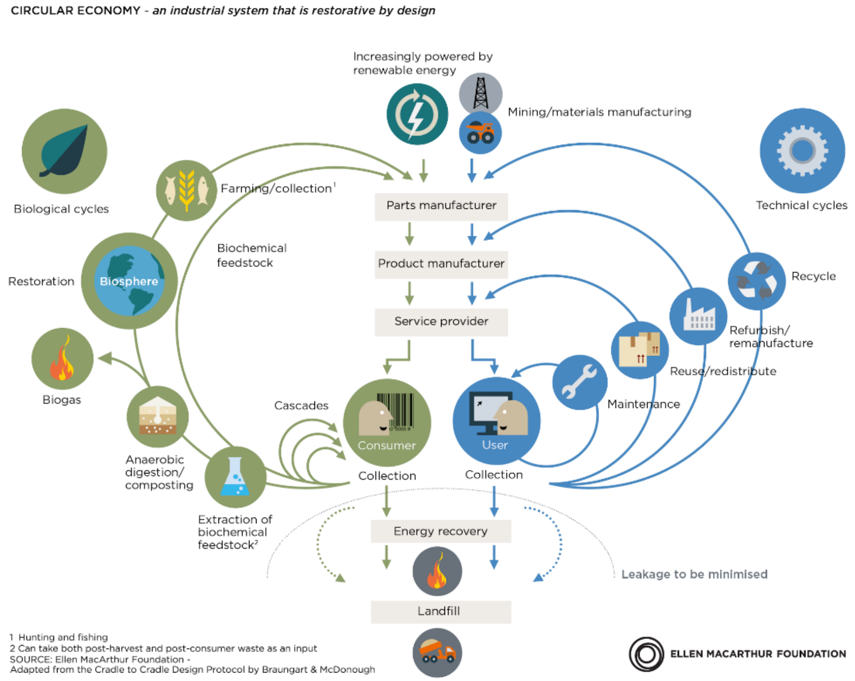


Funded by the Erasmus+ Programme of the European Union

Circular economy model

WOOD IN CIRCLE

- The circular economy model describes the **technical and biological** materials continuously recycled within the system. Biological and technical materials have been separated from each other because their material cycles and the means to create closed material cycles for them are different.
- **Technical materials** are manufactured by people and are mainly based on non-renewable natural resources. The principle of technical material cycles is the sustainable use of non-renewable natural resources, for example, by repairing, re-using and re-manufacturing products, as well as by seeking to return the surplus materials produced during the processing of material and manufacture of the product, as well as the materials contained in the product at its end of life, back into the cycle. An important part of the implementation of technical cycles is material development and product design that support recycling and, for example, extending product life cycles through maintenance.
- Consumption takes places only in **biological cycles** where biologically based materials, such as food, cotton or wood may be returned to circulation through biological processes. Such processes are, for example, anaerobic digestion or composting. Nutrients and biologically-derived materials circulate in the system and enable the renewal of renewable natural resources.



Funded by the Erasmus+ Programme of the European Union

Elements of Technical Cycle

- **Maintenance** – process in which product is kept in a good condition. After maintenance product`s lifetime stays the same.
- **Reuse** – reuse of product after minor maintenance and cosmetic touch-ups in the same purpose it was originally manufactured
- **Refurbishment** refers to measures taken to restore its condition by repairing or replacing components with minor defects.
- **Remanufacturing** refers to a process in which a product is dismantled and parts or components are recovered. Parts are removed from the used product – and assembled to make a new product. Remanufacturing includes quality control and the possibility to add or alter components.
- **Recycling** is a process in which material is recovered – to be used in its original or other purpose, excluding energy use. Recovered material is then used as recycled material.
  - If recycling reduces the quality of the material – the process may be reffered to as «downcycling».
  - The process used to improve quality is called «upcycling».

Funded by the Erasmus+ Programme of the European Union

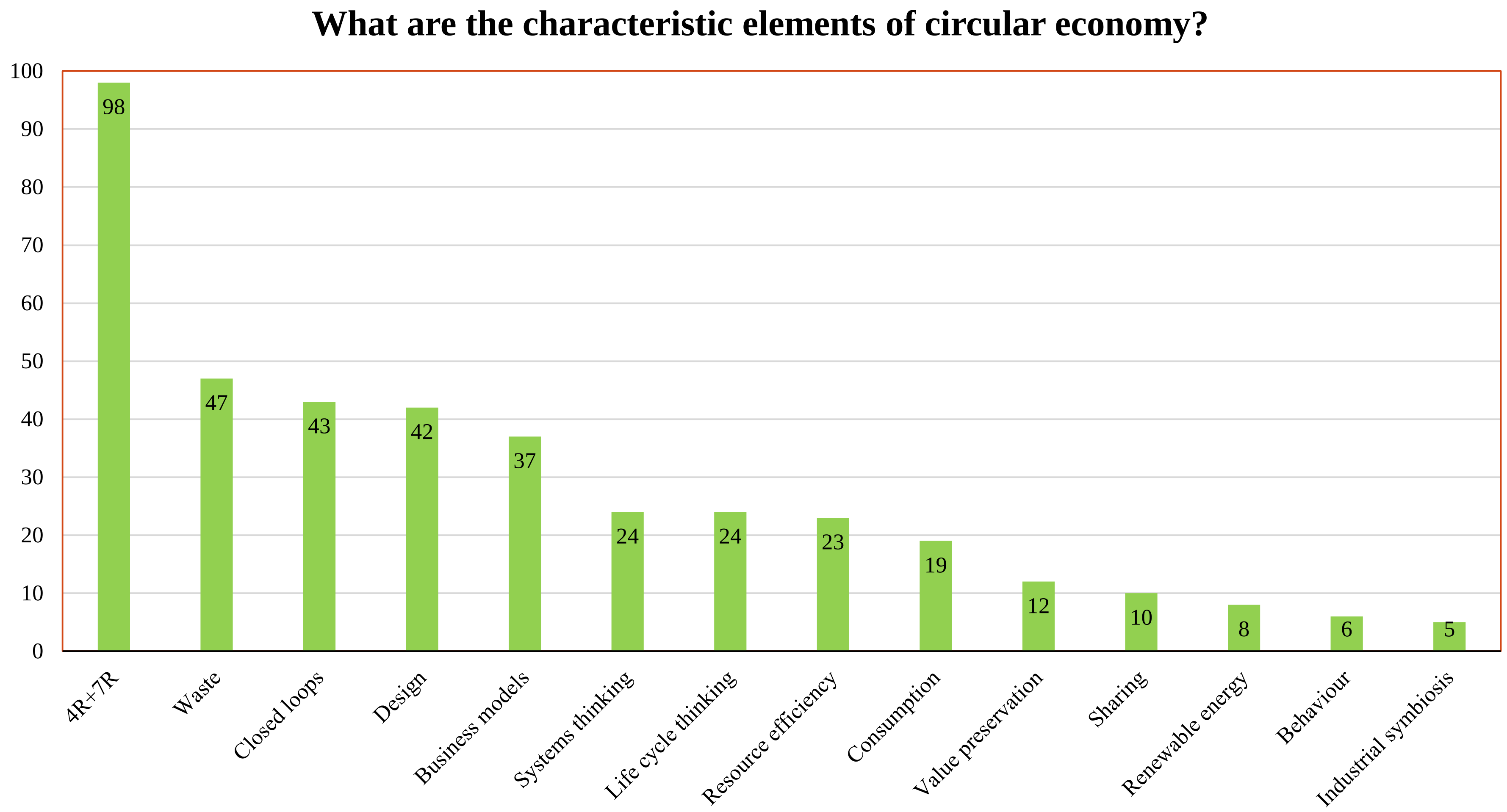
Basic principles of the circular economy

1. **Reuse, remanufacture, recycle**
   - Products should be designed in such a way that they can be **reused**, **remanufactured** or **recycled** to become new material. The aims is to recycle materials so that their value remains as high as possible. In biological cycles, material can be returned to the soil by composting or anaerobic digestion. With regard to technical materials, design has a central role, so that they can be returned to the cycle after use without any deterioration in quality and with minimum energy input.
2. **System level sustainability**
   - **Modularity**, **flexibility** and **adaptability** are key features in a rapidly changing world. The circular economy favours diverse business models and production and business networks, and product and service systems should also be flexible and adaptable. Product life-cycles can be extended through flexibility and versatility. Modular products can be easily repaired, parts are replaceable, and after use the products can be dismantled and recycled or reused.
3. **Use of renewable energy**
   - **Renewable energy** is needed to create a sustainable circular economy as it is naturally cyclical.
4. **System approach**
   - To implement the circular economy it is important to understand how the elements interact with each other, and how the whole system affects smaller areas. At the same time, the aim is that non-linear systems which have feedback loops will play a key role. The effects of different factors and material flows on the whole system have to be understood so that is can be optimised.
5. **Strengthening the biological foundation**
   - Increasing the use of biological materials for the needs of consumption takes place by increasing cascading use. The same biological material is used several times in products, which may have a variable usage need. The objective is that the value of the biological material is reduced as little as possible with each use, and that the nutrients in the biological materials are recovered at the stage where the materials are discarded. Thus the need for virgin natural resources is minimised.

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Characteristic elements of Circular Economy



(Zvirgzdins & Geipele, S., 2020)

Funded by the Erasmus+ Programme of the European Union

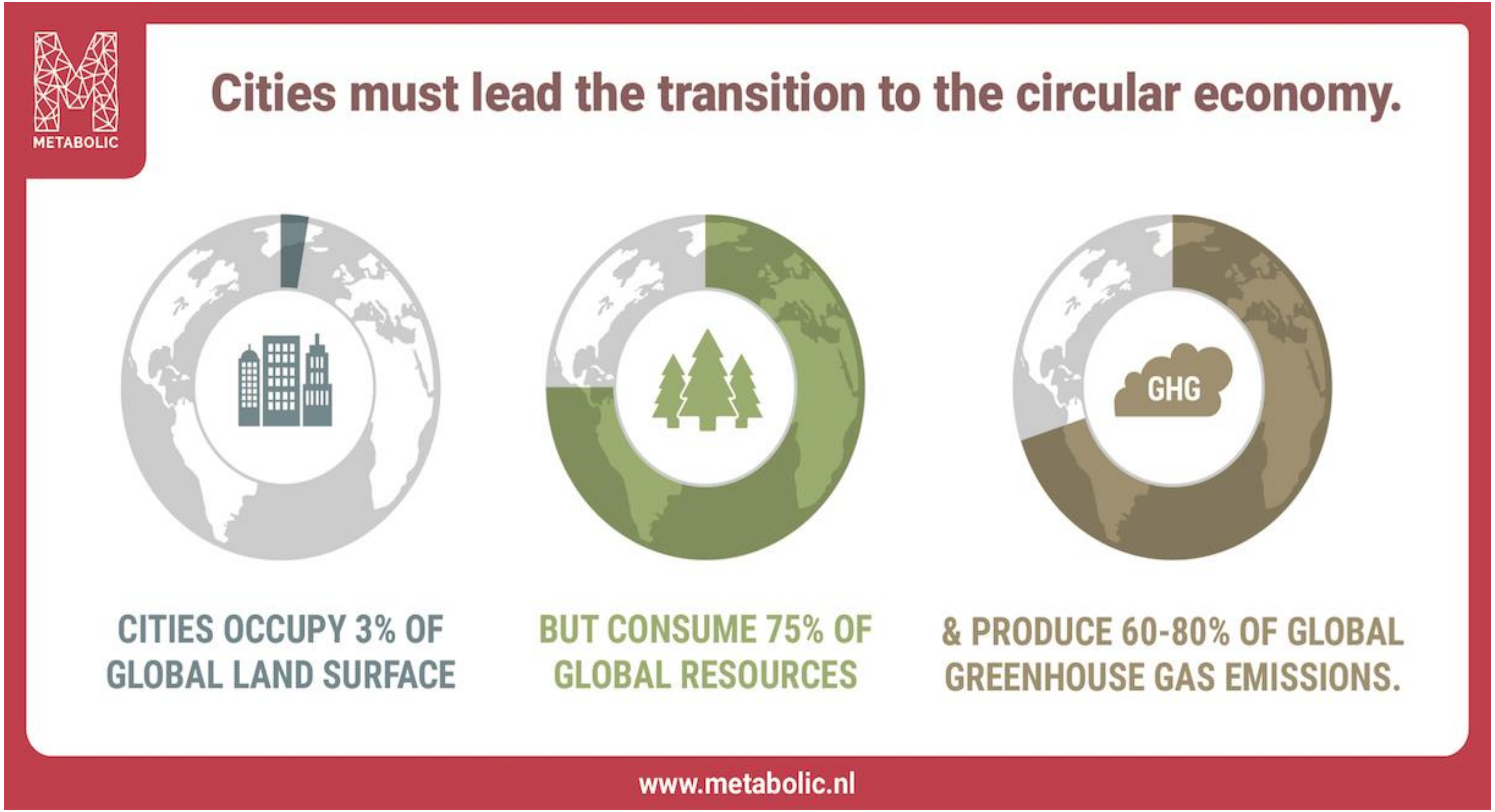
Definitions

WOOD IN CIRCLE

Category	Definition
4R+7R	Principle of multiple use and recovery (reduce, reuse, recycle, remanufacture (4R); refuse, refill, repeat, repair, remediate, reclaim, return (7R) …). In scientific publications this principle is also referred to as 3R principle - reduce, reuse, recycle. However, the amount of Rs and variations is flexible as there are more than 11 'R' activities in totality.
Waste	Reduction of waste generation and waste management.
Closed loops	Flow of materials and resources in a closed system to reduce the volume and speed of resource flow.
Design	Product and service design that includes such elements as long-lasting, regenerative, reuse, recyclability, durability, maintenance and circularity.
Business models	Models describing and visualizing the basic principles of monetization. In the context of the circular economy, the most common are: 1) repair and maintenance; 2) reuse and redistribution; 3) refurbishment and remanufacturing; 4) recycling; 5) cascading and repurposing; 6) organic feedstock business model.
Systems thinking	A system or system approach that points to the necessity for general paradigm shifts to successfully implement the concept of circular economy.
Life cycle thinking	A life-cycle approach to products and resources from the extraction of primary resources to the management or disposal of waste considering ecological, economic and social aspects.
Resource efficiency	Efficient and smart use of raw materials and energy with minimal harm to the environment.
Consumption	Society`s consumption of materials, resources and products, which in the framework of circular economy should aim for minimum volumes.
Value preservation	Preserving the value of a product or material with the aim of preserving the quality of the material or product for as long as possible.
Sharing	Derivative of the 'sharing economy' concept based on a change of ownership model from private goods (washing machines, cars, etc.) to shared products used by more than one household, thus reducing overall demand for the relevant products.
Renewable energy	The use of renewable energy (solar, wind, water, geothermal, bioenergy, wave energy) in the energy sector within the framework of circular economy and the use of renewable resources.
Behaviour	Consumer behaviour related to consumption trends, flexibility to change and paradigm shift in resource use and management.
Industrial symbiosis	Intercompany clusters at the supply chain level where waste from one company serves as a resource for another.

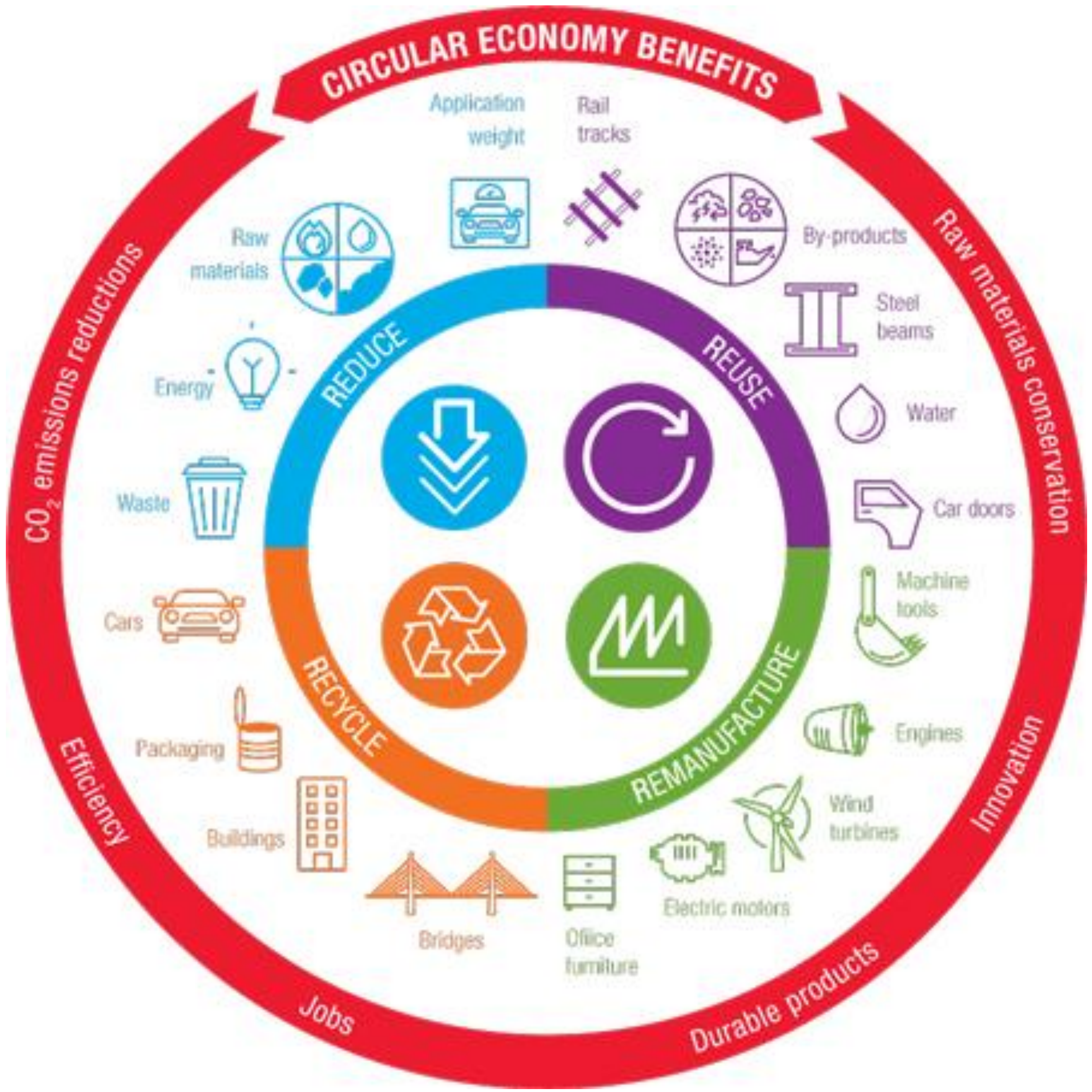
Funded by the Erasmus+ Programme of the European Union

Cities must lead…



Funded by the Erasmus+ Programme of the European Union

Circular economy benefits



Source: https://unctad.org/fr/node/1681

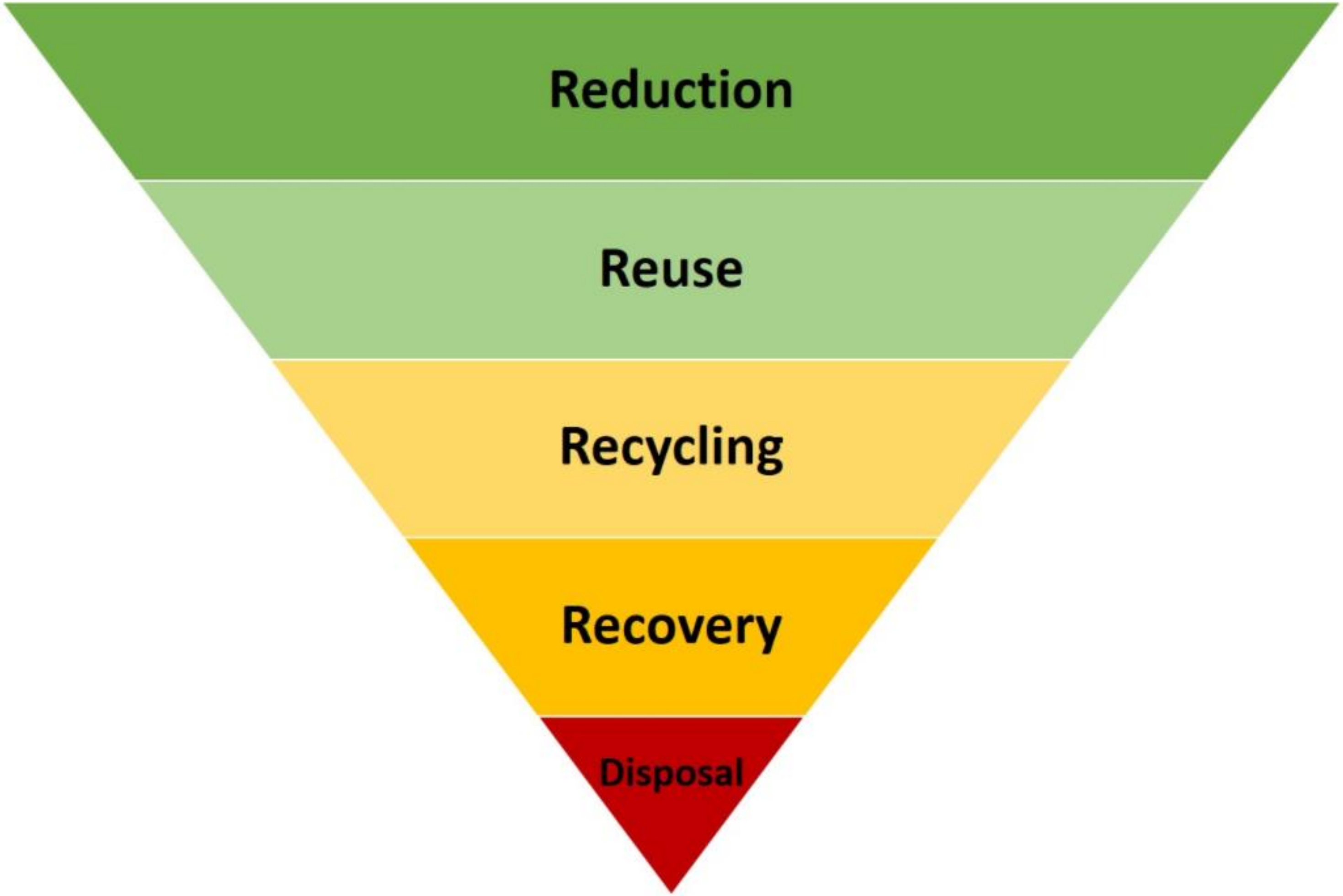
Funded by the Erasmus+ Programme of the European Union

4Rs

- **1. Reduce:** Focuses mainly on the beginning of the life cycle of a product. The aim is to design the product so that its production requires minimal materials and energy. The amount of waste and emissions are also minimized. The consumer can also select, for example, products containing less packaging material or reduce consumption by buying less.
- **2. Reuse:** Means the reuse of a product as it is or the reuse of its components. This reduces the need for new resources.
- **3. Recycle:** This is related to processes in which what is usually classified as waste material is used as a raw material for new materials or products after technical processing. Recycling means a process in which what is usually classified as waste material is used as a raw material for new materials or products after technical processing. The word "recycling" can be used only when the material has been categorized as waste at some point in the process. The objective of recycling is to reduce the need and consumption of virgin raw materials and energy.
- **4. Recover:** At the end of its life cycle, the different materials that can be utilized are separated from the product. Typically, the term refers to industrial scale operation, not private households.

Funded by the Erasmus+ Programme of the European Union

The hierarchy between the 4Rs



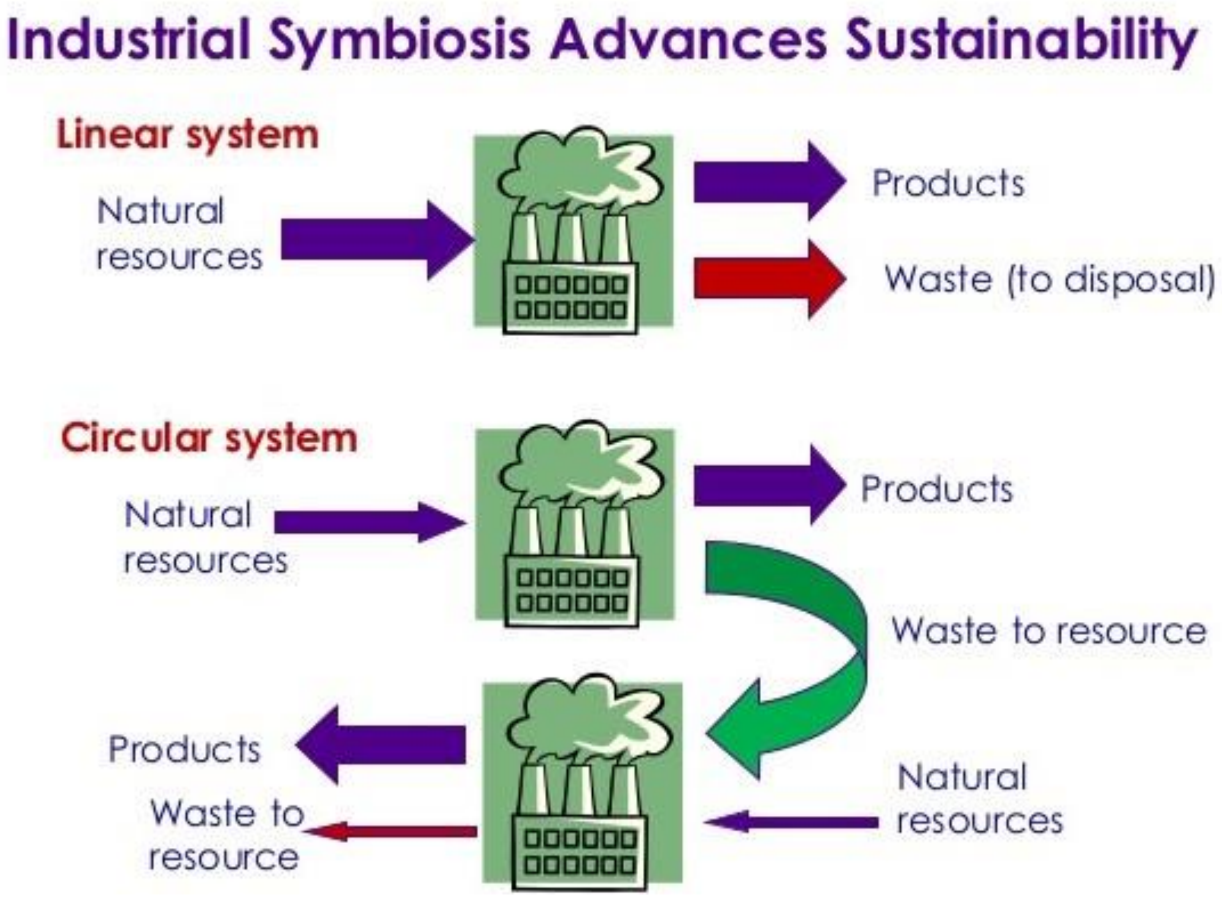
Funded by the Erasmus+ Programme of the European Union

4Rs to 6Rs

- The 4Rs approach can also be expanded to a 6Rs model, in which the additional units are more related to the product and manufacturing processes rather than to materials selection. Additional Rs are **Redesign** and **Remanufacture**.
- When product's functionality and features have been tested in practice, the product can be **redesigned** thereby improving its recyclability, utilization and materials' consumption in the next generation of products.
- **Remanufacture** means a reversed production process where the products and components used are collected for refurbishment and repair so they are like new and are then returned to the market for their original use. After remanufacturing the product has the same features as the equivalent new product and often a warranty that compares with the original. Remanufacture makes it possible to save large amounts of energy and new materials compared to manufacturing a completely new product. Remanufacturing is sometimes also referred to as factory refurbishment.

Industrial symbiosis

- Critical is **cross-sectoral cooperation** between actors where **residue flows** and **waste** are exploited efficiently in other industrial production activities. At its best, it creates **industrial symbiosis** where one company's waste is another's raw material.



Funded by the Erasmus+ Programme of the European Union

Design stage

- The amount of waste can best be affected at the **design stage**, as this is when materials and manufacturing methods can be selected so that production consumes minimal energy and resources. At the same time, the product can be designed in such a way that at the end of its life cycle maintenance, reuse and recycling can be carried out easily and in the most effective way.
- In the design phase the materials used, the characteristics and structure of the product and the production methods will all be selected. It is important to note that about **75% of the product's manufacturing costs are decided in the design phase**.
- Design can be used to slow the circulation of resources and to form increasingly closed circulation. In practice, slowing down material cycles often occurs most naturally, though not necessarily the easiest in practice, by designing the product so that it can be used for as long as possible and that it can also withstand long use. This occurs when the product itself is designed to be reliable and its maintenance in terms of servicing, repair and updates is also effortless and economically appropriate from the customer's point of view. In addition, design strategy can promote reuse, recycling and recovery of the product's parts and materials at the end of the product's life cycle.

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Product design that is economically profitable and implements the principles of the circular economy includes the following elements:

- **Systematic material selection taking the principles of the circular economy into account**
  - Considering the life cycle of each chosen material
- **Optimal design of products with respect to durability, reliability, maintenance and use of material**
  - Use of standardized components
  - Easy condition check of replaceable parts and rapid availability of spare parts and quick replacement
  - Maintenance programme planning and user guidance
- **Taking concrete steps to enable 6R operating measures from the early stages of the planning phase**
  - For example, by promoting the separation of products, parts and materials by marking the dismantling of assemblies (screw joints are easier to take apart than welded joints)
  - Good recyclability and recovery at the end of the life cycle
- **Planning for recovery of by-product flows and waste recovery that arises during product manufacture**
  - For example using surplus material from raw materials (steel sheet etc.)

Funded by the
Erasmus+ Programme
of the European Union

Designer, circular economy and product life cycle

Making an impact as a product designer

- Reducing the use of materials, both in a product itself and its packaging
- Reducing the need to use dangerous and/or rare raw materials
- Favouring the use of locally-sourced raw materials
- Favouring the use of energy-efficient material processes

- Replacing physical prototypes with virtual models
- Minimising material waste through optimised structural design
- Environmentally-friendly and sustainable approach to logistics e.g. minimising waste packaging and considering the location of manufacturing sites

- Ensuring a long product lifespan
  - Maintainability, updateability
- Energy-efficiency (i.e. improving operating efficiency) and environmental impact

- Enabling the application of R6 principles

Stages of a product lifespan

Preproduction

- Gathering and enriching raw materials
- Processing raw materials for use in technologies
- Transport, distribution, storage, and packaging of materials

Manufacturing

- Transport and storage of semi-finished and purchased parts etc.
- Product manufacturing
- Product packaging, transport, and storage

Operation

- Operation and maintenance

Circular economy

- R6

Funded by the Erasmus+ Programme of the European Union

Design for Environment (DFE)

- Taking the company's stakeholders’ (the board of directors, investors, customers, competitors, society etc.) **attitude to the circular economy** into account
- Creating **environmental objectives** (for example, complying with environmental legislation, taking customer’s environmental awareness into account, reducing the economic consequences of environmental obligations, etc.).
- The selection of indicators (e.g. the degree of recycling, dismantling time, energy consumption, total mass, proportion of hazardous or rare materials of the entire material requirement, innovation from the DFE perspective, etc.)
- Integrating DFE into the systematic product design process
- Integrating DFE into the product development organisation along with other product development programmes (such as extending the product family, development of production conditions, etc.)

Funded by the Erasmus+ Programme of the European Union

DFE guidelines by Black and Decker

1. **Reduce** the use of hazardous and rare materials in the finished product and also think about the waste produced during manufacture
2. **Reduce** the need for raw material by reducing the number of components
3. Promote the **recyclability** and separation of product components
4. Shorten the product’s dismantling time
5. Reduce the product’s need for energy use

Funded by the Erasmus+ Programme of the European Union

Design for Reliability

- **Reliability** is an essential factor in product design and use. Reliable products lead to a reduction in unforeseen problems and the resulting production losses, better security, and lower maintenance costs, and lower life cycle costs overall. The following considerations may affect product reliability in the design phase:
    - simplicity in implementing the product's functionalities
    - care in selecting subcontracting partners
    - a preference for components with demonstrated reliability
    - utilizing known manufacturing methods
    - careful drawing up of the requirements list, and evaluation and understanding of the various requirements that have an impact on reliability
    - accuracy of technical calculations and ensuring their suitability for the parts in question (for example, with sufficiently accurate analyses the safety margin in stress calculations can be reduced and thus it will be possible to achieve the structural design using less material)
    - taking processing and operating conditions into account, for example, in assembly, transport and end use
    - appropriate testing

Funded by the Erasmus+ Programme of the European Union

Design for Reuse

- In **reuse**, whole parts and components that have been removed from devices are used almost as they are to become part of a new product
- The basis for reuse is the experience that the lifetimes of the various components in devices and machines are not equal. When a device is at the end of its life cycle as a system, it may contain several components that have plenty of life still left. A used component can be used in the new product as it is or after repair. The reuse of parts is complicated by the difficulty of evaluating the quality of the used part, especially from the perspective of its remaining lifetime and that it has adequate functionality. In addition, customers may have a negative attitude to products sold as new that contain used components.

Funded by the Erasmus+ Programme of the European Union

Design for Recycling

- In recycling, material that has been classified as waste can be extracted from old products through intermediate stages (dismantling, shredding, separation, processing into a usable form) for the manufacture of new product components
- **Recyclability** can be facilitated in **design** as follows:
  - minimizing the number of parts
  - minimising the use of different types of material
  - prefering recyclable materials
  - avoiding hazardous and harmful materials, and enabling easy separation
  - promoting the removal and separation of materials by using connection methods that are easy to dismantle and by using standardised material markings

Funded by the Erasmus+ Programme of the European Union

Design for Remanufacturing

- At its simplest, remanufacture means a process where the product is dismantled, the parts are cleaned, repaired and replaced, and subsequently the product is **re-assembled** so it is like new with regard to its operating condition. The main specifications for a remanufactured product are:
  - The main components are from a used product
  - The used product has been dismantled to an extent sufficient to determine the condition of its components
  - Used parts have been cleaned to remove traces of corrosion, for example
  - Defective used parts are either reconditioned or replaced with new ones or with functioning used parts
  - Appropriate methods are used to recondition parts such as machining
  - After re-assembly, the device is checked to ensure it functions like new

Funded by the Erasmus+ Programme of the European Union

Designer and Remanufacturing Process

- The designer can contribute to remanufacture of the product as follows:
  - There must be clear instructions on how to dismantle the product
  - Parts that are to be cleaned and reconditioned must be marked on the product itself
  - Parts that are prone to wear parts, etc., and have to be checked must be marked on the product
  - The fastest wearing parts should be placed (if possible) close to each other and easily accessible to allow for replacement
  - Parts that are the easiest to damage should be designed to be particularly easy to remove

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Construction industry

- 50% of total raw material use
- 40% CO_2 emissions
- 36% of energy consumption

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Built Environment and Real Estate Industry

- Buildings produce CO_2 in two ways:
  - During their exploitation through heating etc. (approximately 35% of the total EU CO_2 emissions)
  - During construction and manufacturing of the building materials (approximately 5% of the total EU CO_2 emissions)

Funded by the
Erasmus+ Programme
of the European Union

WOOD IN CIRCLE

Circular Economy in Built Environment

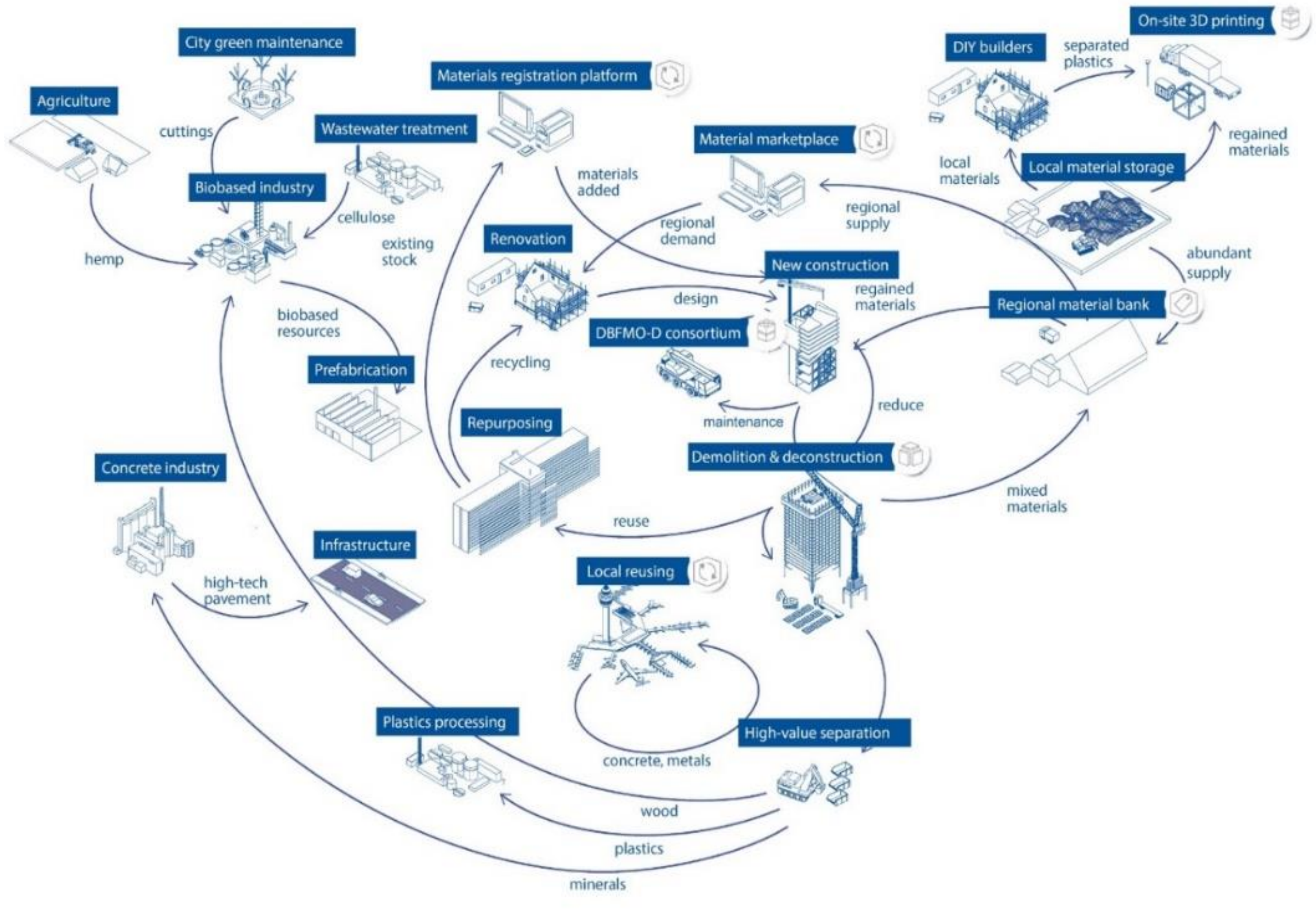
- Long-lasting design
- Maintenance
- Repair
- Reuse
- Remanufacturing
- Repurposing
- Refurbishing
- Recycling

→

Key sustainable construction objectives:

- ❑ Respect to materials selection
- ❑ Closing material loops
- ❑ Eliminating solid, liquid, gaseous emissions

Process relation in circular economy



(UK Green Building Council, 2017)

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Barriers for implementing circular economy

Financial	Social	Institutional	Technical
High Transition Costs	Lack of awareness and sense of urgency	The linear mindset has deep roots	Products are designed to dispose
Upfront Investment	Resistance to change	Complicated or inelastic regulatory structures	Lack of information exchange
Economic viability of recycling		Limited integrated action and leadership	Lack of metrics to measure circularity

(World Economic Forum, 2018)

Funded by the Erasmus+ Programme of the European Union

Circular economy related GHG reductions

- **17 000 MtCO_2 eq. global reduction by 2030** using such circular economy strategies as electric, shared, and autonomous vehicles, food waste reduction, regenerative and healthy food chains, passive houses, urban planning, and renewable energy (MacArthur *et al.*, 2015)
- **7 500 MtCO_2 eq. global reduction by 2030** using recovery and reuse, lifetime extension, sharing and service model, circular design, and digital platforms (Blok *et al.*, 2016; Schroeder *et al.*, 2018).
- **~75 MtCO_2 eq. (3–10 %) reduction by 2030 in Finland, France, the Netherlands, Spain and Sweden** using material efficiency, which is related to substituting half of the virgin materials used with recycled materials, and doubling the product-life-time of long-lived consumer products (Wijkman & Skånberg, 2015)

Funded by the Erasmus+ Programme of the European Union

Performance economy

- Walter Stahel`s Inertia Principle:
  - *‘Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured. Replace or treat only the smallest possible part in order to maintain the existing economic value of the technical system’.*

Funded by the Erasmus+ Programme of the European Union

WOOD IN CIRCLE

Thank you for attention!