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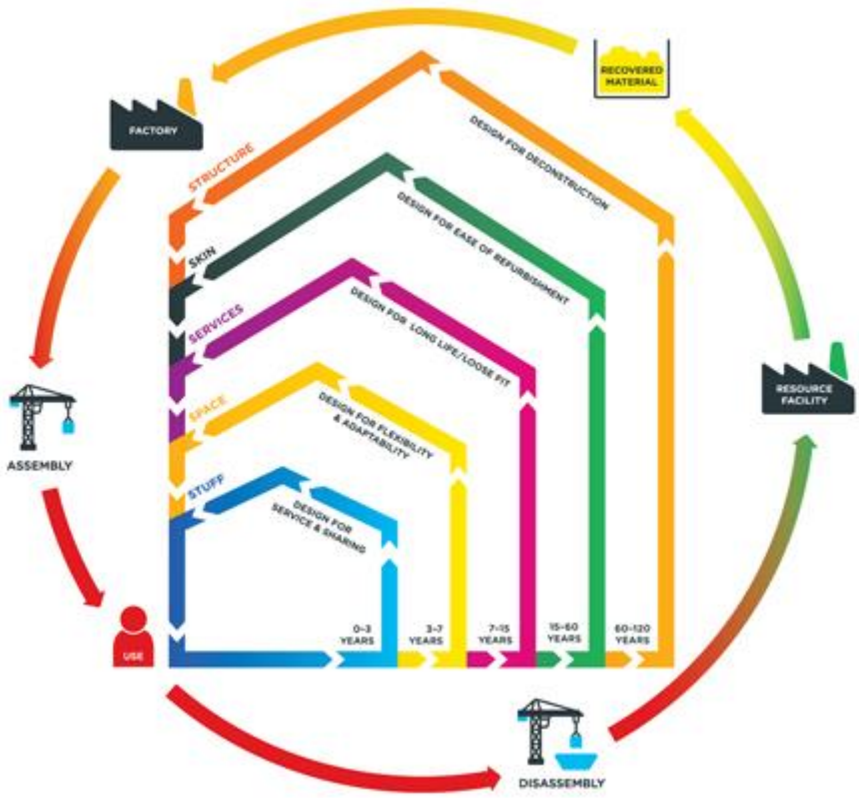
BIM-LCA Construction Project

Title: Circular Economy



1 – Aims

The objectives of this Circular Economy tutorial are as follows:

- Learning about the advantages of using LCA as tool to reduce environmental impact.
- Knowing about state of technology and methodology for environmental assessments.
- Knowing about the typology of LCA phases.
- Knowing the results of a life cycle assessment (LCA) that compares environmental impacts for products and processes.

2 - Learning methodology

- The lecturers will give an explanation about fundamentals of LCA and different application of about 60 minutes.
- Students will read this tutorial and follow the steps shown in the tutorial.
- Interactive tutorials - discussions, completion of assessment material
- Lectures - including guest lecturers from industry and different institutions.
- Review of topical content - e.g. reports, videos, podcasts
- In order to evaluate the success of the lesson, a questionnaire will be held for the students.

3 - Tutorial duration

The implementation described in this tutorial will be carried out through the BIM-LCA Project website by self-learning.

3 lesson hours are suitable for this training.

4 – Necessary teaching recourses

Computer room with PCs with internet access.

Required software: Microsoft Office.

5 – Contents & tutorial

5.1 – Introduction. Life cycle assessment.

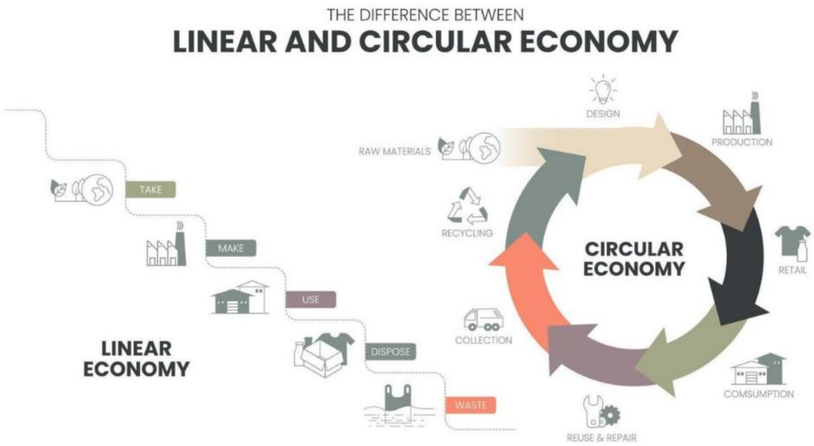
5.1.1. Definition

Circular economy is a model of resource production and consumption in any economy that involves sharing, leasing, reusing, repairing, refurbishing, and/or recycling existing materials and products for as long as possible. The concept aims to tackle global challenges such as climate change, biodiversity loss, waste, and pollution by emphasizing the design-based implementation of the three base principles of the model. The three principles required for the transformation to a circular economy are: designing out waste and pollution; keeping products and materials in use and regenerating natural systems.

The idea and concepts of a circular economy have been studied extensively in academia, business, and government over the past ten years. It has been gaining popularity because helps to minimize carbon emissions and the consumption of raw materials, open up new market prospects, and, principally, increase the sustainability of consumption [1].

In a linear economy, natural resources are turned into products that are ultimately destined to become waste because of the way they have been designed and manufactured. In contrast, a circular economy model aims to transition from a 'take-make-waste' approach to a more restorative and regenerative system. It employs reuse, sharing, repair, refurbishment, remanufacturing and recycling to create a closed-loop system, reducing the use of resource inputs and the creation of waste, pollution, and carbon emissions. The circular economy aims to keep products, materials, equipment, and infrastructure in use for longer, thus improving the productivity of these resources. Waste materials and energy should become input for other processes through waste valorization: either as a component for another industrial process or as regenerative resources for nature.

Circular economy strategies can be applied at various scales, from individual products and services to entire industries and cities. For example, industrial symbiosis is a strategy where waste from one industry becomes an input for another, creating a network of resource exchange and reducing waste, pollution, and resource consumption [2].



5.1.2. History and aims

The concept of a circular economy cannot be traced back to one single date or author, rather to different schools of thought [3], including industrial ecology, biomimicry, and cradle-to-cradle design principles. Industrial ecology is the study of material and energy flows through industrial systems, which forms the basis of the circular economy. Biomimicry involves emulating nature's time-tested patterns and strategies in designing human systems. Cradle-to-cradle design is a holistic approach to designing products and systems that considers their entire life cycle, from raw material extraction to end-of-life disposal and seeks to minimize waste and maximize resource efficiency. These interrelated concepts contribute to the development and implementation of the circular economy.

In 2010, the concept of circular economy started to become popular internationally after the publication of several reports [4]. The European Union introduced its vision of the circular economy in 2014, with a New Circular Economy Action Plan launched in 2020 that "shows the way to a climate-neutral, competitive economy of empowered consumers".

Currently, the climate emergency and environmental challenges induce companies and individuals in rethink their production and consumption patterns. The circular economy is framed as one of the answers to these challenges. Key macro-arguments in favour of the circular economy are that it could enable economic growth that does not add to the burden on natural resource extraction but decouples resource uses from the development of economic welfare for a growing population, reduces foreign dependence on critical materials, lowers CO_2 emissions, reduces waste production, and introduces new modes of production and consumption able to create further value. Corporate arguments in favour of the circular economy are that it could secure the supply of raw materials, reduce the price volatility of inputs and control costs, reduce spills and waste, extend the life cycle of products, serve new segments of customers, and generate long-term shareholder value. A key idea behind the circular business models is to create loops throughout to recapture value that would otherwise be lost.

Of particular concern is the irrevocable loss of raw materials due to their increase in entropy in the linear business model. Starting with the production of waste in manufacturing, the entropy increases further by mixing and diluting materials in their manufacturing assembly, followed by corrosion and wear and tear during the usage period. At the end of the life cycle, there is an exponential increase in disorder arising from the mixing of materials in landfills.

Circular development is directly linked to the circular economy and aims to build a sustainable society based on recyclable and renewable resources, to protect society from waste, and to be able to form a model that no longer considering resources as infinite. This new model of economic development focuses on the production of goods and services, taking into account environmental and social costs. Circular development, therefore, supports the circular economy to create new societies in line with new waste management and sustainability objectives that meet the needs of citizens.

However, critiques of the circular economy suggest that proponents of the circular economy may overstate the potential benefits of the circular economy. Therefore, a future where waste no longer exists, where material loops are closed, and products are recycled indefinitely is, in any practical sense, impossible. There is a lack of clarity as to whether the circular economy is more sustainable than the linear economy and what its social benefits might be, in particular, due to diffuse contours. Other issues include the increasing risks of cascading failures which are a feature of highly interdependent systems, and have potential harm to the general public. When implemented in bad faith, touted "Circular Economy" activities can often be little more than reputation and impression management for public relations purposes by large corporations and other vested interests; constituting a new form of greenwashing. It may thus not be the panacea many had hoped for.

Linear "take, make, dispose" industrial processes, and the lifestyles dependent on them, use up finite reserves to create products with a finite lifespan, which end up in landfills or in incinerators. The circular approach, by contrast, takes insights from living systems. It considers that our systems should work like organisms, processing nutrients that can be fed back into the cycle—whether biological or technical—hence the "closed loop" or "regenerative" terms usually associated with it.

5.1.3. Scope

The circular economy can have a broad scope. Researchers have focused on different areas such as industrial applications with both product-oriented and natural resources and services, practices and policies to better understand the limitations that the circular economy currently faces, strategic management for details of the circular economy and different outcomes such as potential re-use applications and waste management.

The circular economy includes products, infrastructure, equipment, and services and applies to every industry sector. It includes 'technical' resources (metals, minerals, fossil resources) and 'biological' resources (food, fibres, timber, etc.). Most schools of thought advocate a shift from fossil fuels to the use of renewable energy and emphasize the role of diversity as a characteristic of resilient and sustainable systems. The circular economy includes a discussion of the role of money and finance as part of the wider debate, and some of its pioneers have called for a revamp of economic performance measurement tools. One example of a circular economy model is the implementation of renting models in traditional ownership areas (e.g., electronics, clothes, furniture, transportation). By renting the same product to several clients, manufacturers can increase revenues per unit, thus decreasing the need to produce more to increase revenues. Recycling initiatives are often described as circular economy and are likely to be the most widespread models.

5.1.4 Emergence of the idea

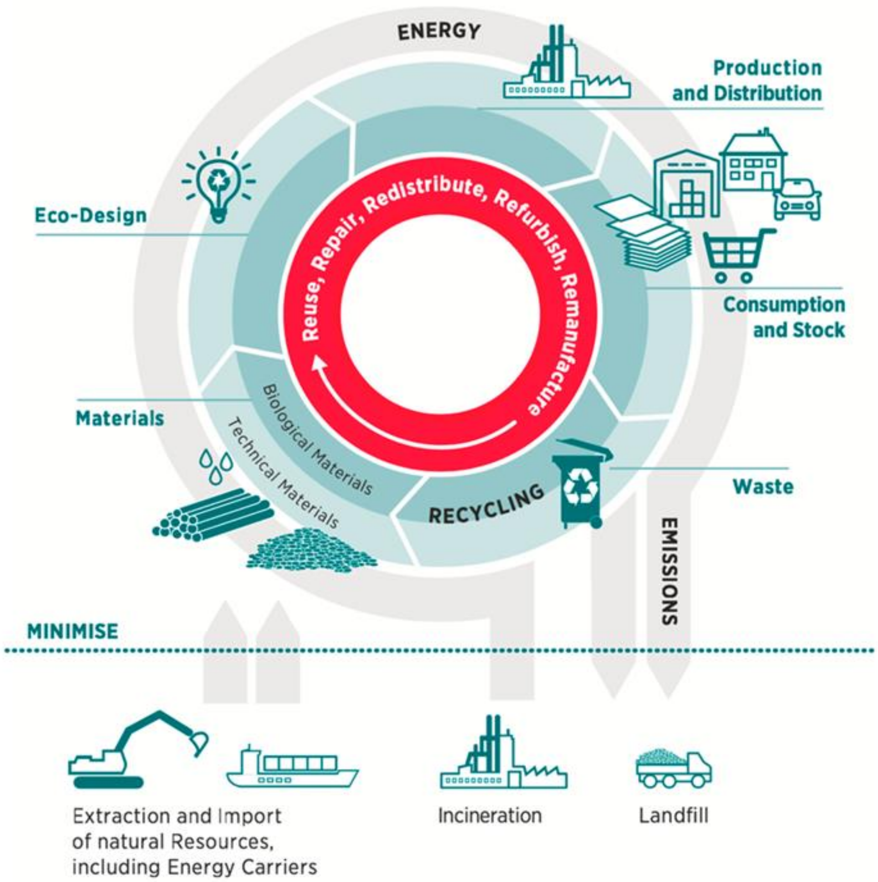
In their 1976 research report to the European Commission, "The Potential for Substituting Manpower for Energy," Walter Stahel and Genevieve Reday sketched the vision of an economy in loops (or a circular economy) and its impact on job creation, economic competitiveness, resource savings and waste prevention. The report was published in 1982 as the book Jobs for Tomorrow: The Potential for Substituting Manpower for Energy [5].

Most frequently described as a framework for thinking, its supporters claim it is a coherent model that has value as part of a response to the end of the era of cheap oil and materials and, moreover, contributes to the transition to a low-carbon economy. In line with this, a circular economy can contribute to meeting the COP 21 Paris Agreement. The emissions reduction commitments made by 195 countries at the COP 21 Paris Agreement are not sufficient to limit global warming to 1.5 °C. To reach the 1.5 °C ambition, it is estimated that additional emissions reductions of 15 billion tonnes of CO_2 per year need to be achieved by 2030. Circle Economy and Ecofys estimated that circular economy strategies may deliver emissions reductions that could bridge the gap by half [6].

5.2– Towards the circular economy

In 2013, a report was released entitled Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition. The report, commissioned by the Ellen MacArthur Foundation and developed by McKinsey & Company, was the first volume of its kind to consider the economic and business opportunity for the transition to a restorative, circular model. Using product case studies and economy-wide analysis, the report details the potential for significant benefits across the EU. It argues that a subset of the EU manufacturing sector could realize net materials cost savings worth up to $630 billion annually towards 2025—stimulating economic activity in the areas of product development, remanufacturing and refurbishment. Towards the Circular Economy also identified the key building blocks in making the transition to a circular economy, namely in skills in circular design and production, new business models, skills in building cascades and reverse cycles, and cross-cycle/cross-sector collaboration [7].

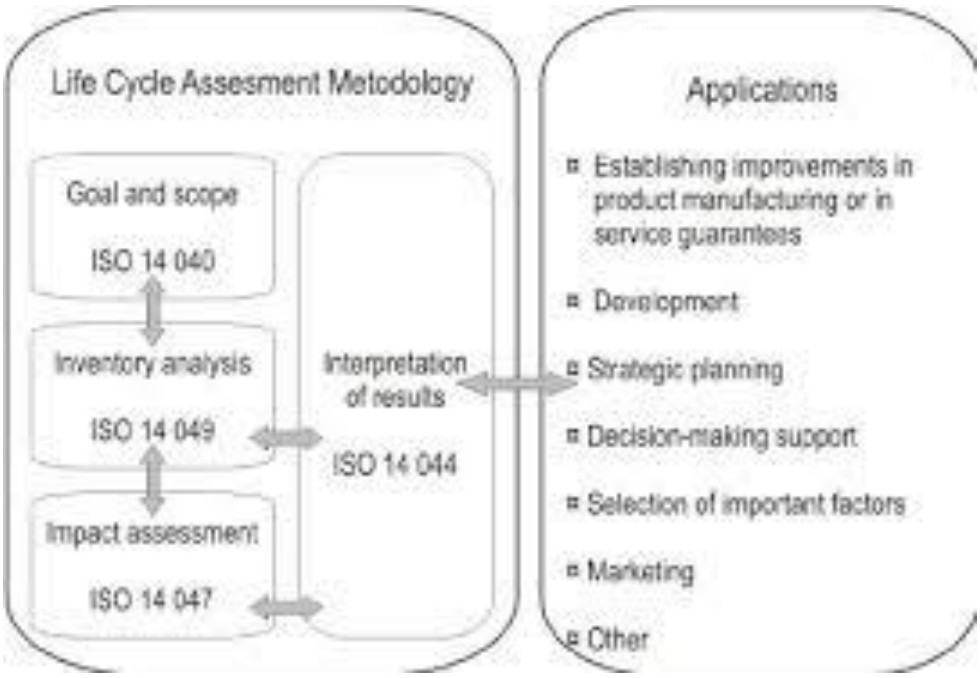
Another report by WRAP and the Green Alliance (called "Employment and the circular economy: job creation in a more resource efficient Britain"), done in 2015 has examined different public policy scenarios to 2030. It estimates that, with no policy change, 200,000 new jobs will be created, reducing unemployment by 54,000. A more aggressive policy scenario could create 500,000 new jobs and permanently reduce unemployment by 102,000 [8].



On 2 March 2022 in Nairobi, representatives of 175 countries pledged to create a legally binding agreement to end plastic pollution by the end of the year 2024. The agreement should address the full lifecycle of plastic and propose alternatives including reusability.

5.3 - LCA Standards and Design Guides.

Product designs that optimize durability, ease of maintenance and repair, upgradability, re-manufacturability, separability, disassembly, and reassembly are considered key elements for the transition toward circularity of products. Standardization can facilitate related innovative, sustainable, and competitive advantages for European businesses and consumers. Design for standardization and compatibility would make product parts and interfaces suitable for other products and aims at multi-functionality and modularity. A Product Family Approach has been proposed to establish commonality, compatibility, standardization, or modularization among different products or product lines. The basic standardization of LCA is ISO 14000. However, it is necessary to use the different standardization according to goals, inventory analysis, impact of the analysis and interpretation of the results.



Not all types of recycling processes (one circularity process) have equal impact on health and sustainability. For sustainability and health, the circularity process designs may be of crucial importance. Large amounts of electronic waste are already recycled but far from where they were consumed, with often low efficiency, and with substantial negative effects on human health and the foreign environment.

Recycling should therefore reduce environmental impacts of the overall product/service provision system assessed based on the life-cycle assessment approach.

While the initial focus of the academic, industry, and policy activities was mainly focused on the development of re-X (recycling, remanufacturing, reuse, etc.) technology, it soon became clear that the technological capabilities increasingly exceed their implementation. To leverage this technology for the transition toward a circular economy, various stakeholders have to work together. This shifted attention towards business-model innovation as a key leverage for 'circular' technology adaption.

Circular business models can be defined as business models that are closing, narrowing, slowing, intensifying, and dematerializing loops, to minimize the resource inputs into and the waste and emission leakage out of the organizational system. This comprises recycling measures (closing), efficiency improvements (narrowing), use phase extensions (slowing), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerializing). These strategies can be achieved through the purposeful design of material recovery processes and related circular supply chains.

Circular business models, as the economic model more broadly, can have different emphases and various objectives, for example: extend the life of materials and products, where possible over multiple 'use cycles'; use a 'waste = food' approach to help recover materials, and ensure those biological materials returned to earth are benign, not toxic; retain the embedded energy, water, and other process inputs in the product and the material for as long as possible; Use systems-thinking approaches in designing solutions; regenerate or at least conserve nature and living systems; push for policies, taxes and market mechanisms that encourage product stewardship, for example 'polluter pays' regulations.

Circular business models are enabled by circular supply chains. In practice, collaboration for circular supply chains can enable the creation, transfer, and/or capture of value stemming from circular business solutions. Collaboration in supply chains can extend to downstream and upstream partners and include existing and new collaboration. Similarly, circular supply chain collaboration allows innovation into the circular business model, focusing on its processes, products, or services.

Building on circular business model innovation, digitalization, and digital technologies (e.g., internet of things, big data, artificial intelligence, blockchain) are seen as a key enabler for upscaling the circular economy. Also referred to as the data economy, the central role of digital technologies for accelerating the circular economy transition is emphasized within the Circular Economy Action Plan of the European Green deal. The smart circular economy framework illustrates this by establishing a link between digital technologies and sustainable resource management. This allows assessment of different digital circular economy strategies with their associated level of maturity, providing guidance on how to leverage data and analytics to maximize circularity (i.e., optimizing functionality and resource intensity).

5.3.1. Circular economy standard BS 8001:2017

To provide authoritative guidance to organizations implementing circular economy (CE) strategies, in 2017, the British Standards Institution (BSI) developed and launched the first circular economy standard "BS 8001:2017 Framework for implementing the principles of the circular economy in organizations". The circular economy standard BS 8001:2017 tries to align the far-reaching ambitions of the CE with established business routines at the organizational level. It contains a comprehensive list of CE terms and definitions, describes the core CE principles, and presents a flexible management framework for implementing CE strategies in organizations. Little concrete guidance on circular economy monitoring and assessment is given, however, as there is no consensus yet on a set of central circular economy performance indicators applicable to organizations and individual products.

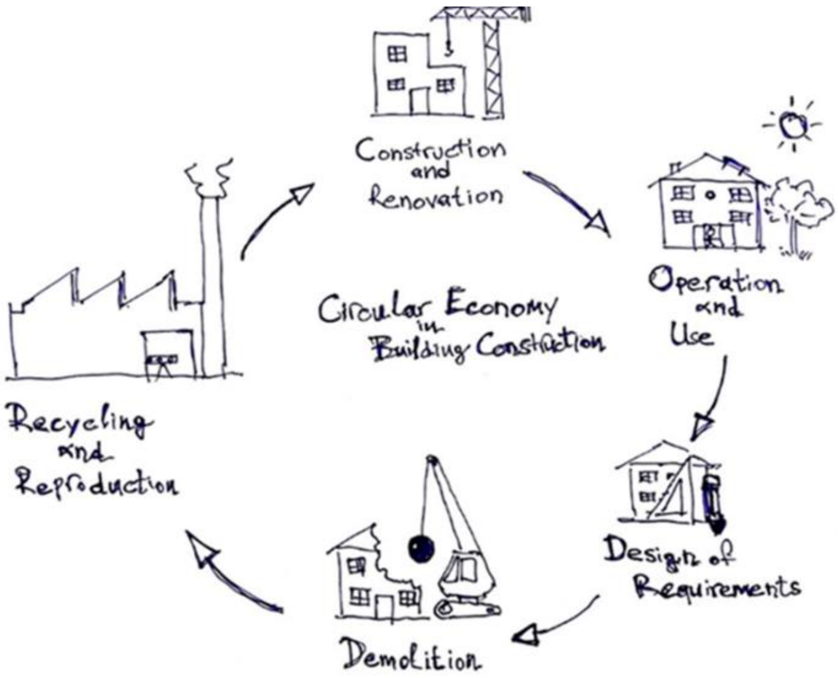
In 2018, the International Organization for Standardization (ISO) established a technical committee, TC 323, in the field of circular economy to develop frameworks, guidance, supporting tools, and requirements for the implementation of activities of all involved organizations, to maximize the contribution to Sustainable Development.

5.4– LCA and Construction and Building Technology

The construction sector is one of the world's largest waste generators. The circular economy appears as a helpful solution to diminish the environmental impact of the industry. The main causes of the construction's environmental impact are found in the consumption of non-renewable resources and the generation of contaminant residues, both of which are increasing at an accelerating pace.

Decision making about the circular economy can be performed on the operational (connected with particular parts of the production process), tactical (connected with whole processes) and strategic (connected with the whole organization) levels. It may concern both construction companies as well as construction projects (where a construction company is one of the stakeholders). End-of-life buildings can be deconstructed, hereby creating new construction elements that can be used for creating new buildings and freeing up space for new development. Modular construction systems can be useful to create new buildings in the future and have the advantage of allowing easier deconstruction and reuse of the components afterwards (end-of-life buildings).

Another example that fits the idea of circular economy in the construction sector on the operational level, there can be pointed walnut husks, that belong to hard, light, and natural abrasives used for example in cleaning brick surfaces. Abrasive grains are produced from crushed, cleaned and selected walnut shells. They are classified as reusable abrasives.



3D printing of construction materials is a modern technology that offers more architectural freedom for complex shape geometries. 3D printing of concrete is less labor-intensive and has more efficient materials usage compared to traditional methods. It also eliminates the need for formwork, which can be up to 60% of the construction costs.

Portland cement is the most used binder in the production of concrete. However, the production of Portland cement is significantly energy-demanding and contributes to the global carbon footprint. Clinker-free building materials are design to replace one of the most polluting materials: Portland Cement-based concrete. Therefore, alternative systems with less environmental impact are in demand.

A first attempt to measure the success of circular economy implementation was done in construction companies. Therefore, there is a need of qualified professionals working on circular economy in the construction sector who can contribute to creating new posts and economic growth.

5.5 – Software

The most widely used software in Circular Economy are:

- SimaPro
- Brousted model 5

- Team (EcoBilan)
- GaBi
- MEEUP method
- GREET
- MIPS
- GRANTA
- Aggregain
- KCL-ECO 3.0
- Okala Ecodesign
- LCA calculator
- One-Click LCA

For the BIM-LCA approach of the course, the recommended programmes are GRANTA and One-Click LCA.

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6 - Deliverables

To evaluate the success of the application, students will have to answer an online questionnaire.

7- What we have learned (learning outcomes)

1. Recognise, explain and discuss how materials and energy flow through our economic system.

2. Apply a systems approach to developing circular economy models to keep materials and energy at their highest value.

3. Recognise and distinguish between strategies to achieve a more circular economy, including resource and waste management , eco efficiency, clean production, industrial ecology, and how technology such as big data facilitates this.

4. Understand how to apply life cycle approaches to quantifying environmental impacts of products or systems, including embodied energy.

5. Have experienced or been exposed to energy systems concepts, including sustainable options for production, utilisation and optimisation of energy.

6. Scope, investigate, critically analyse and synthesise information to design a creative and sustainable alternative to a "linear" model in a predefined context.