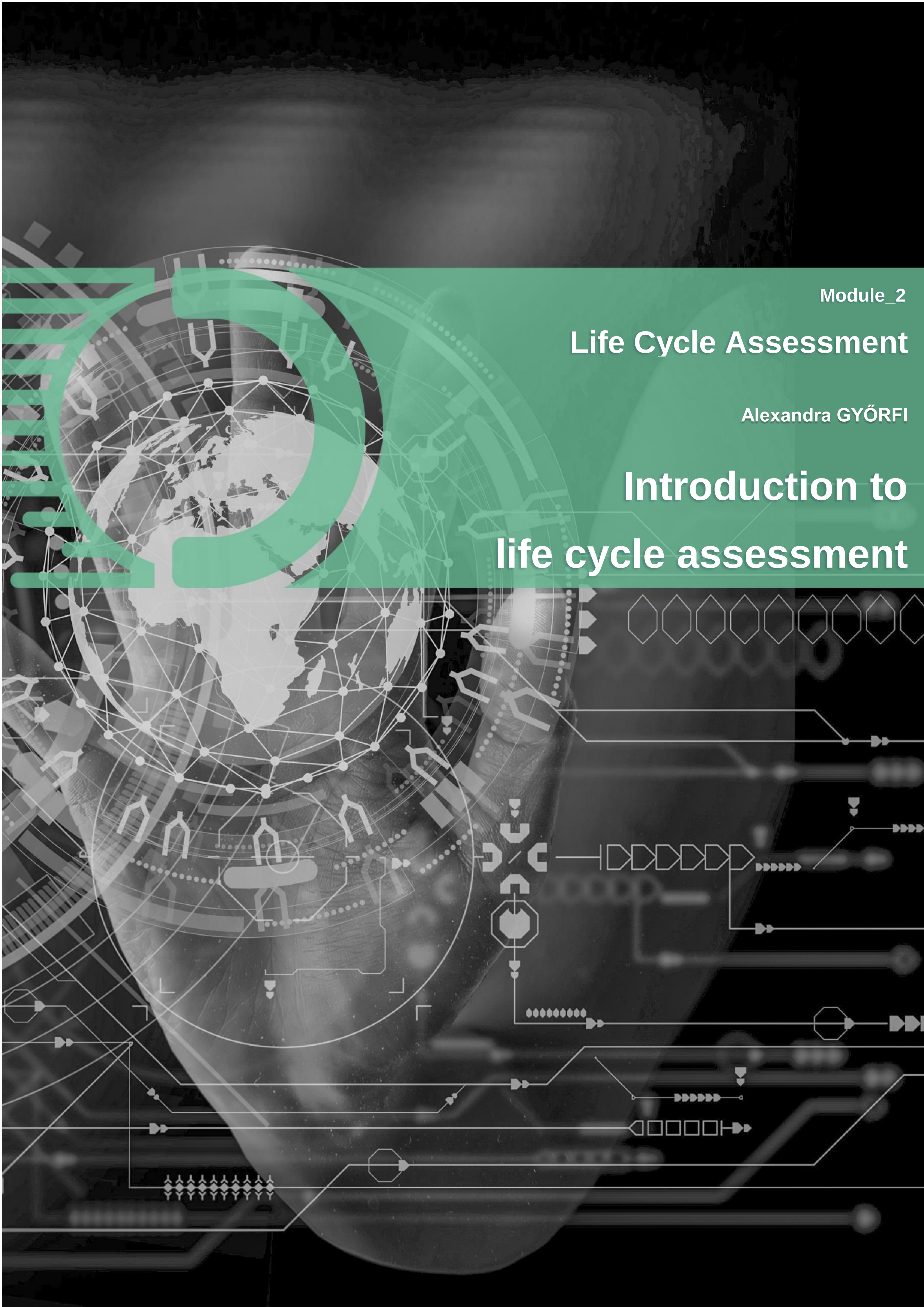

Module_2

Life Cycle Assessment

Alexandra GYŐRFI

Introduction to life cycle assessment

Module_2

Life Cycle Assessment

Alexandra GYŐRFI

Introduction to life cycle assessment

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2 CHANGES BETWEEN HUMANITY AND NATURE

2-1. Figure: 'people in a sunny park' (made with Image Creator powered by DALL·E)

For a long time, the pollution that contaminated the water, air, and soil was filtered during natural self-purification. In recent years, the harmonious bond between people and their environment has been disrupted. Each day, we transform the natural resources that are extracted, and we use those resources to create products that have different structures. The production and consumption of synthetic substances result in waste and pollution that is released into the natural environments in growing and concentrated spatial quantities. Production and waste generation continue to rise as a result of increasing consumption, which can be attributed to population expansion and the mindset of the society that values consumption.

The natural self-purification processes in soil, water, and air are overburdened and lack the capacity to handle the growing pollution. As a result, the environment has deteriorated, and both humans and other creatures of life have suffered harm to their health and wellbeing. In addition, the overuse of natural resources, which is being fueled by an expanding population and a culture of consumerism, is unsustainable and, if left unchecked, will eventually result in their depletion. By eliminating pollution, waste, and overconsumption and adopting sustainable habits, humanity could once again live in peace with the environment and preserve it for future generations.

2-2. Figure: 'acid rain on statues' (made with Image Creator powered by DALL·E)

3 CONTAMINANTS IN THE ENVIRONMENT

3-1. Figure: 'energy production'
(made with Image Creator powered by DALL·E)

Pollutants may reach the environment in a variety of ways. Typical sources of pollution include:

_Manufacturing, mining, and energy production are examples of industrial processes that can emit chemicals and other contaminants.

_Pesticides and fertilizers used in agricultural techniques have the potential to contaminate water and soil.

_Pollutants as carbon monoxide, nitrogen oxides, and particulate matter are released into the atmosphere during transportation.

_Contaminants can be released when waste disposal facilities, such as landfills and sewage treatment plants, malfunction.

_Environmental pollution can also be caused by household activities such the usage of pesticides, cleaning products, and personal care items.

_By increasing the frequency and severity of natural disasters like floods and wildfires, which can spread pollutants and waste into the environment, climate change can also contribute to pollution.

It's critical to keep in mind that pollution affects ecosystems and populations throughout the world and that it can be spread over great distances by wind and water currents.

3-2. Figure: 'forest wildfire'
(made with Image Creator powered by DALL·E)

4 CHEMICAL ENTRY OF POLLUTANTS

Chemical decomposition is the process by which a chemical substance is broken down into simpler compounds or components by chemical reactions. It is sometimes referred to as chemical breakdown or chemical degradation. This can be caused by human activity, such as industrial processes or waste disposal, or it can happen naturally, such as by the impact of sunshine, heat, or other environmental variables.

There are numerous ways in which chemical decomposition can take place, including biological degradation, oxidation, hydrolysis, and photolysis. When certain additional chemicals, enzymes, or microorganisms are present, these reactions can be catalyzed. The chemical composition of the complex, the presence of additional chemicals, temperature, and environmental pH can all affect how quickly a chemical decomposes.

They might involve intricate physical and chemical processes that result in the formation of newly created pollutants or the modification of already-existing ones. Pollutants in the atmosphere can interact with sunlight and other substances to create secondary pollutants, such as ground-level ozone, which is dangerous to human health and can lead to respiratory issues. Chemical reactions can also significantly contribute to the introduction of contaminants into the environment in soil and water. In the presence of other pollutants, chemical reactions can also take place and produce harmful byproducts. For instance, the breakdown of PCBs in soil or water can lead to the creation of extremely poisonous dioxins and furans.

Chemical decomposition is a crucial process for eliminating pollutants, but it can also be hazardous to the environment if it discharges toxic byproducts or harmful substances. Understanding the processes by which chemicals break down can help us minimize or lessen the effects that certain substances have on the environment.

4.1 BIOLOGICAL DEGRADATION

4-1. Figure: 'biodegradation of organic waste' (made with Image Creator powered by DALL·E)

The breakdown of organic matter in the environment by microorganisms like bacteria and fungi is referred to as biological degradation. This process assists in the recycling of carbon, nutrients, and other components in the environment and is a natural and vital component of the ecosystem. It is the primary way that organic matter is recovered in nature. During the process, microorganisms eat organic compounds and break them down into simpler parts like carbon dioxide, water, and minerals. It is possible for biodegradation to take place in a variety of conditions, including soil, water, and air, and it can be utilized to remove waste and pollution including pesticides, sewage, and oil spills.

The type of pollutant, the surrounding environment, and the presence of other microorganisms can all affect how quickly a substance degrades. Certain microorganisms are better suited to degrade particular types of pollutants, and some pollutants can be broken down more quickly than others. Biotechnology can also improve degradation, for example by using genetically modified microorganisms or enzymes that can breakdown particular contaminants.

The following are a few instances of how the environment is impacted by biological degradation:

- Organic waste is broken down by microorganisms into nutrient-rich soil during composting.
- Microorganisms clean up pathogens and contaminants from wastewater throughout the sewage treatment operations.
- By digesting the hydrocarbons in the oil, marine microorganisms can break down oil spills.
- Microbes can be utilized in soil remediation to break down contaminants including pesticides, heavy metals, and polychlorinated biphenyls (PCBs) that are present in the soil.
- When it comes to the biodegradation of contaminants in groundwater, microorganisms that reside there can break down contaminants like gasoline and diesel fuel.
- With the use of biofilters or biotrickling filters, microorganisms can breakdown contaminants from the air, such as volatile organic compounds (VOCs).

Overall, biological degradation is a natural process that is vital to the harmony and efficiency of ecosystems. Despite the fact that it can exacerbate contamination, it nevertheless holds great promise for reducing the negative effects of waste and pollution on the environment.

4.2 OXIDATION

4-2. Figure: 'burning of coal'
(made with Image Creator powered by DALL·E)

By removing electrons from an atom or molecule, a chemical reaction known as oxidation occurs, which produces oxides. Both natural occurrences and human-induced processes might cause this to happen. This process has the potential to be exothermic, releasing heat, as well as produce new, highly reactive chemical molecules. It has both positive and negative effects on contaminants that enter the environment. Oxidation has the potential to reduce the danger of some contaminants by breaking them down.

Volatile organic compounds (VOCs), for example, can be degraded by sunlight through a process known as photo-oxidation or through chemical interactions with other substances, such as ozone. Less dangerous chemicals may arise as a result of this. On the other hand, oxidation can also result in the creation of more dangerous substances, such as the common air pollutants sulphur dioxide (SO2) and nitrogen oxides (NOx). These substances, which are created when fossil fuels are burned, can harm the environment and people's health.

4.3 HYDROLYSIS

4-3. Figure: 'algal bloom'
(made with Image Creator powered by DALL·E)

In a chemical reaction called hydrolysis, water is utilized to dissolve a substance. The water molecule splits into two components, which then interact with the substance being broken down. The substance that is being broken down is frequently separated into smaller molecules or components during hydrolysis.

In some circumstances, hydrolysis can degrade contaminants and lessen their danger. Including some pesticides and herbicides, that can degrade in the soil or water, creating less dangerous compounds. However, hydrolysis can also result in the formation of more dangerous substances. Certain chemicals can produce toxic or reactive by-products during hydrolysis that can be dangerous for both people and the environment. For instance, fertilizers containing nitrogen and phosphorus compounds may be applied during agricultural operations. These compounds can react with water to produce nitrate and phosphate ions. Once in waterways, these ions can cause harmful algal blooms and other ecological issues.

4.4 PHOTOLYSIS

4-4. Figure: 'plastic chair broken down by photolysis'
(made with Image Creator powered by DALL·E)

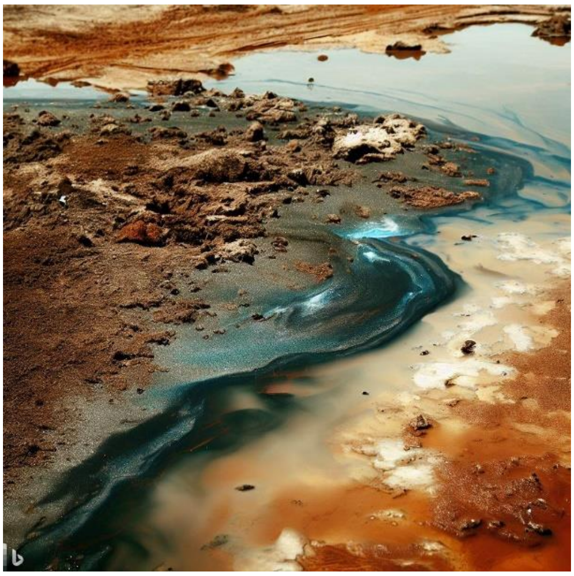
A chemical reaction in which a substance is broken down by the energy of light is called photolysis, often referred to as photodissociation. This process may take place naturally, such as when sunlight acts, or it may occur when artificial light sources are used. A photon of light is absorbed by the compound, giving the energy required to rupture the chemical bonds in the molecule. This may cause the release of smaller particles or elements, as well as the creation of new chemical substances like radicals.

In some circumstances, photolysis can degrade contaminants and lessen their danger. Through photo-oxidation, sunlight can break down some pollutants like volatile organic compounds (VOCs), resulting in the formation of less dangerous compounds. However, the same process can also result in the emergence of more dangerous substances. Secondary pollutants like ozone can be produced by the photolysis of some contaminants.

5 HARMFUL ENVIRONMENTAL EFFECTS OF POLLUTION

5.1 CONTAMINATION OF SOIL AND WATER

There are many ways that agricultural practices can contaminate land and water. Using pesticides and fertilizers, for instance, can cause these chemicals to leak into groundwater, contaminating drinking water supplies and harming aquatic life. Livestock operations can also contaminate soil and water by discharging manure and other waste materials into surrounding streams.



5-1. Figure: 'contamination of soil and water' (made with Image Creator powered by DALL·E)

The quality of soil and water can be significantly impacted by industrial activity. For instance, when chemicals and other pollutants are released into the air by factories and power plants, they may land on the ground and enter waterways. Accidental spills or leaks, as well as improperly managed or stored hazardous items, can pollute land and water.

Another significant factor in soil and water pollution is waste disposal. The soil is the most typical disposal area for waste materials. Inadequately managed trash and the byproducts of its decomposition are washed away by rainfall on the soil's surface and seep into the groundwater, frequently jeopardizing important water bases and subtly lowering water quality. Physical and chemical circumstances have an impact on their intensity.

The inappropriate disposal of hazardous materials can potentially damage soil and water, as can untreated sewage. The inappropriate management of municipal and industrial wastewater, as well as occasionally tainted rainwater from accidents, leads to both indirect and direct pollution of surface waters. Hazardous compounds' solubility in water makes it easier for other materials to be released.

Acid rain, chemical spills, and oil spills are other significant sources of pollution. It may take years or even decades to clean up after them and restore the quality of the soil and water.

Pollution of the soil and water is aggravated by climate change. For instance, soil erosion brought on by heavy downpours may interfere with plant growth. Water shortages and more difficult access to safe drinking water are two effects of droughts. Increased flooding and landslides, which can contaminate water supplies with sediment and other contaminants, can be brought on by changes in precipitation patterns.

5.2 AIR POLLUTION

Burning, or combustion, is a substantial contributor to air pollution. Sulfur dioxide, nitrogen oxides, and particulate matter are released into the atmosphere when fuels like coal, oil, and natural gas are burned to produce power or heat. Both the environment and human health may be negatively impacted by these contaminants.

Methane and carbon dioxide emissions from production-related industrial and agricultural operations can also contribute to the greenhouse effect, a major driver of global warming and climate change. Powerful greenhouse gases like methane are emitted via landfills, livestock operations, and the production of oil and gas.

5-2. Figure: 'air pollution'
(made with Image Creator powered by DALL·E)

Organic compounds break down and emit a variety of gases, including ammonia and hydrogen sulfide, which can have unpleasant odors and be hazardous to both human health and the environment. These gases may be released from places like agricultural operations, composting facilities, and landfills.

5.3 SPREAD OF PESTS AND INFECTION RISK

Pests like flies and rodents like rats and mice may multiply as a result of poor waste management procedures. Due to their attraction to waste, these pests may grow and feed on it if it is not properly collected, stored, and disposed of. This might cause these pests to multiply rapidly, endangering the public's health.

Implementing appropriate waste management practices, such as frequent garbage collection and disposal, suitable waste storage, and the use of pest control techniques, is crucial for controlling the spread of illness and reducing the population of pests. To lessen the danger of disease transmission from pests, proper sanitation and hygiene procedures are crucial.

5-3. Figure: 'litter on the street'
(made with Image Creator powered by DALL·E)

5.4 DETERIORATION OF THE ENVIRONMENT

Eutrophication is the process by which a body of water becomes excessively rich in nutrients. This is mostly caused by the fertilizer and other nutrient runoff from urban and agricultural regions into waterways. The overgrowth of aquatic plants and algae caused by this excessive nitrogen intake lowers the amount of dissolved oxygen in the water. This reduction in oxygen can be dangerous to fish and other aquatic life and encourage the growth of toxic algae, endangering the general public's health. The discharge of nutrients into rivers must be controlled and monitored, and the adoption of ecologically friendly agricultural methods must be encouraged in order to prevent eutrophication.

5-4. Figure: 'duckweed over a river'
(made with Image Creator powered by DALL·E)

Summer smog is a form of air pollution that is mostly brought on by emissions from cars, power plants, and industrial sites and is characterized by elevated levels of ground-level ozone and particulate matter. During the summer, when there is an abundance of sunshine, this photochemical smog is particularly common in urban areas. Exposure can result in respiratory issues, cardiovascular disease, and early mortality rates. The use of public transportation, promotion of alternative energy sources, and regulation of vehicle and industrial facility emissions are all necessary for preventing summer smog.

5-5. Figure: 'smog over the city'
(made with Image Creator powered by DALL·E)

Winter smog, also referred to as industrial smog, is brought on by emissions from commercial and domestic heating systems that burn coal, oil, and natural gas as fuel. The most prevalent locations for this kind of smog are cities with factories and power plants, or heavily inhabited areas with separately heated family homes. In addition to harming vegetation, winter pollution can also result in respiratory issues, cardiovascular disease, and early death. Regulating industrial and domestic heating system emissions, promoting the use of cleaner energy production and heating methods, and encouraging energy saving are all necessary to combat winter air pollution.

5-6. Figure: 'unsafe disposal of waste'
(made with Image Creator powered by DALL·E)

Unsafe disposal of both hazardous and non-hazardous waste constitutes a significant environmental problem that puts the public's health and the environment at danger. A number of issues, such as soil and water contamination, air pollution, and wildlife damage, can result from the illegal dumping of waste in forests, waterways, and public spaces. Promoting public education and understanding of proper trash disposal methods, enforcing laws and penalties against unlawful dumping, and offering safe and convenient waste disposal options are all necessary to prevent illegal waste disposal.

6 ENVIRONMENTAL PROBLEMS IN THE CENTURY

There are many natural problems that are considered to be important in the 21st century, but some of the most pressing issues include the following.

6.1 GLOBAL WARMING AND CLIMATE CHANGE

Global warming and climate change are often used interchangeably, but they technically refer to different things.

6-1. Figure: 'oil spill on the ocean next to an oil rig' (made with Image Creator powered by DALL·E)

The gradual rise in the world's average temperature that has been recorded over the past century is referred to as global warming. The combustion of fossil fuels, which releases greenhouse gases like carbon dioxide and methane into the atmosphere, is the main factor causing this temperature rise. The Earth's surface warms up as a result of these gases' ability to retain solar heat.

Contrarily, the term "climate change" refers to a larger spectrum of changes that the Earth's climate is undergoing as a result of global warming and other factors. Along with an increase in global temperature, climate change also causes changes in precipitation patterns, a rise in sea levels, and an increase in the frequency of extreme weather events. Both natural and human factors contribute to climate change, with the burning of fossil fuels and the subsequent rise in greenhouse gas emissions constituting the main human-caused factor.

6.2 EFFECTS OF MATERIAL RESIDUES

Pesticides, heavy metals, and plastic residues are examples of toxic chemical substances that can have an adverse effect on the environment, animals, and human health. Heavy metals and pesticides can build up in the soil and water, hazardous to plants and animals, and even dangerous to human health. Plastic remnants can be mistaken for food by birds and other creatures, resulting in malnutrition and death, or they can be consumed by marine life and cause asphyxia, starvation, and death.

6.3 BIODIVERSITY LOSS

6-2. Figure: 'habitat loss'
(made with Image Creator powered by DALL·E)

Another significant environmental issue of the century is the loss of biodiversity. As a result of habitat loss, overfishing, and pollution, there are fewer plant and animal species, which can have an adverse effect on how well ecosystems function and how well ecosystem services are provided.

6.4 WATER SCARCITY

Another crucial problem in the twenty-first century is the availability of fresh water. Numerous factors, including population increase, climate change, and rising water consumption, are exerting pressure on water supplies around the world. This is causing a water shortage in many areas, which may limit how much water is available for consumption, agriculture, and industry.

6.5 DEPLETION OF FOSSIL ENERGY SOURCES

Fossil fuels like coal, oil, and natural gas have long been the primary source of energy for human civilisation, but their supplies are finite and not renewable. Environmental issues like air pollution, oil spills, and land degradation are caused by the extraction, transportation, and combustion of these fuels. Additionally, the primary cause of greenhouse gas emissions, which contribute to climate change, is the burning of fossil fuels. To lessen the usage of fossil fuels and the emission of greenhouse gases, it is crucial to identify sustainable and renewable energy sources.

7 ENVIRONMENTAL THINKING

7-1. Figure: 'interconnections between environmental factors'
(made with Image Creator powered by DALL·E)

Today, environmental thinking has become more complex. Researchers no longer study the effects of individual factors, but rather their interconnections. In addition to environmental problems, global thinking also deals with social problems - as their cause and result alike.

The most important social problems are overpopulation, food insecurity, diseases, epidemics, pandemics, and concerns about peace and safety. Regarding these, two important observations can be made: their magnitude is significantly influenced by human activities, and their main source is exceeding the assimilation capacity of the earth.

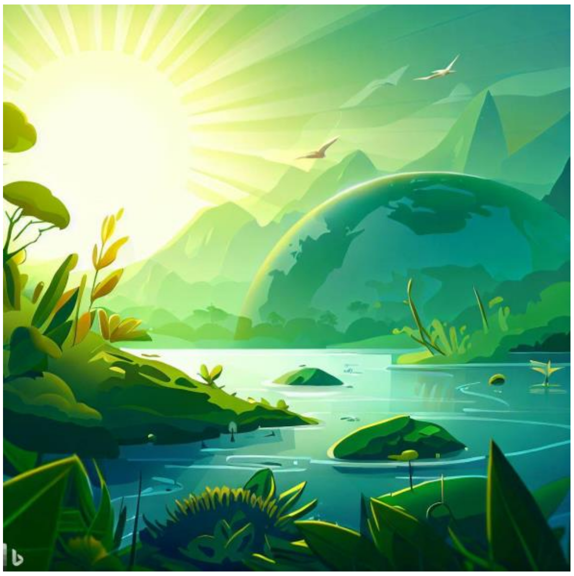
Through environmental thinking and sustainable development, we can meet the current needs without making it impossible to meet the needs of future generations. In a broader sense, the concept also refers to sustainable economic, ecological, and social development, while in a narrower sense, it is limited to environmentally sustainable development. We must maintain the services provided by natural resources by seeking alternative solutions while preserving their quality.

7.1 SUSTAINABLE DEVELOPMENT

The capacity of the environment to process pollutants must be met as one of the general requirements for sustainable development, as well as the reasonable use of non-renewable resources, the rate of which is influenced by both technological advancement and the substitutability of depleted resources with renewable ones. In the case of renewable natural resources, it is crucial that their usage be equal to or lower than their natural or planned capacity for regeneration because only then can they qualify as sustainable.

7-2. Figure: 'woods and groundwater as semi-renewable energy sources'
(made with Image Creator powered by DALL·E)

From the perspective of sustainable development, we can distinguish three groups of natural resources: renewable, semi-renewable and non-renewable. Semi-renewable energy sources are natural resources that can be restored but their natural renewal process is often slower than the pace at which they are utilized. Some types of woods and groundwater are examples of semi-renewable energy sources. Although these resources can be replaced by natural processes, excessive use, or exploitation of them can cause depletion and the loss of their beneficial properties. However, they can be utilized in the same way as completely renewable energy sources with advance planning for regeneration.



7-3. Figure: 'natural resources and ecosystems' (made with Image Creator powered by DALL·E)

Three key pillars have supported sustainable development over the years: the environmental and natural pillar, the economic pillar, and the social pillar.

The conservation and protection of natural resources and ecosystems, such as air, water, land, and biodiversity, are the main objectives of the environmental-natural pillar. To preserve the ecosystem over time, it highlights the necessity of using natural resources sustainably and minimizing waste and pollution.

7-4. Figure: 'green technology and industries' (made with Image Creator powered by DALL·E)

The economic pillar seeks to advance economic growth and development while ensuring resource efficiency and minimizing adverse effects on the community and the environment. It places a strong emphasis on the necessity of adopting sustainable production and consumption practices, using renewable energy sources, and creating green technology and industries.

The social pillar prioritizes the advancement of social justice, inclusivity, and equity as well as the defense of human rights and raising the standard of living for all people. It places a strong emphasis on the need of having access to necessities like clean water, healthcare, and education as well as on advancing gender equality and giving underprivileged groups more power.

To secure a healthy environment, a thriving economy, and a just society for both the present and future generations, sustainable development attempts to strike a balance between the three pillars.

7.2 ECO-DESIGN

At its core, eco-design is a design methodology that aims to maximize a system's positive environmental effects while minimizing its negative ones. With this strategy, the full life cycle of a product is taken into account, from the extraction of raw materials through its eventual disposal or recycling. Eco-design frequently use the life cycle assessment (LCA) method to examine a product's environmental impact at each step of its life cycle.

7-5. Figure: 'urban planning'
(made with Image Creator powered by DALL·E)

Urban planning, architecture, engineering, and industrial design are just a few of the disciplines where these ideas might be used. Eco-design, for instance, can entail selecting materials that are regenerative, recyclable, and non-toxic as well as reducing the use of energy and resources during production and transportation.

Eco-design includes social and ethical considerations in addition to environmental ones. For instance, it can take into account a product's ability to improve the lives of the people who work on its manufacturing or its social impact. They might also think about a product's ethical implications, such as if it is made of ethically and sustainably derived materials.

It is important to promote a sustainable lifestyle and a circular economy in addition to developing environmentally friendly systems and products. This entails encouraging consumers to reuse and recycle things whenever possible and creating products that are durable, repairable, and recyclable.

8 ISO 14000

In order to measure the results of these forms of planning based on environmental thinking in some way, a system of standards was developed, with the help of which the environmental performance of various products and processes can be managed and evaluated in a unified system.

A framework for managing environmental responsibilities inside organizations is provided by the ISO 14000 set of international standards. To keep up with changing environmental difficulties and challenges, these standards have undergone updates and revisions since their initial publication in 1996.

Environmental management subjects such environmental policy, planning, implementation, operation, performance evaluation, and remedial action are all included in the ISO 14000 standards. The standards give businesses direction and best practices for creating and implementing an EMS that is customized to their unique environmental risks and impacts.

Under the main environmental management standard framework there are 6 subcategories in which these standards are sorted:

1. Environmental management systems
2. Environmental auditing and related environmental investigations
3. Environmental labelling
4. Environmental performance evaluation
5. Greenhouse gas and climate change management and related activities
6. Life cycle assessment

A list of the standards that are currently in effect under each subcategory:

8.1 ENVIRONMENTAL MANAGEMENT SYSTEMS

number	**title**
ISO 14001:2015	Environmental management systems — Requirements with guidance for use
ISO 14002-1:2019	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 1: General
ISO 14004:2016	Environmental management systems — General guidelines on implementation
ISO 14005:2019	Environmental management systems — Guidelines for a flexible approach to phased implementation
ISO 14006:2020	Environmental management systems — Guidelines for incorporating ecodesign
ISO 14007:2019	Environmental management — Guidelines for determining environmental costs and benefits

ISO 14008:2019	Monetary valuation of environmental impacts and related environmental aspects
ISO 14009:2020	Environmental management systems — Guidelines for incorporating material circulation in design and development
ISO 14051:2011	Environmental management — Material flow cost accounting — General framework
ISO 14052:2017	Environmental management — Material flow cost accounting — Guidance for practical implementation in a supply chain
ISO 14053:2021	Environmental management — Material flow cost accounting — Guidance for phased implementation in organizations

8.2 ENVIRONMENTAL AUDITING AND RELATED ENVIRONMENTAL INVESTIGATIONS

number	**title**
ISO 14015:2022	Environmental management — Guidelines for environmental due diligence assessment
ISO 14016:2020	Environmental management — Guidelines on the assurance of environmental reports
ISO 14017:2022	Environmental management — Requirements with guidance for verification and validation of water statements

8.3 ENVIRONMENTAL LABELLING

number	**title**
ISO 14020:2022	Environmental statements and programmes for products — Principles and general requirements
ISO 14021:2016	Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)
ISO 14024:2018	Environmental labels and declarations — Type I environmental labelling — Principles and procedures
ISO 14025:2006	Environmental labels and declarations — Type III environmental declarations — Principles and procedures
ISO 14026:2017	Environmental labels and declarations — Principles, requirements and guidelines for communication of footprint information
ISO/TS 14027:2017	Environmental labels and declarations — Development of product category rules
ISO/TS 14029:2022	Environmental statements and programmes for products — Mutual recognition of environmental product declarations (EPDs) and footprint communication programmes

8.4 ENVIRONMENTAL PERFORMANCE EVALUATION

number	**title**
ISO 14030-1:2021	Environmental performance evaluation — Green debt instruments — Part 1: Process for green bonds
ISO 14030-2:2021	Environmental performance evaluation — Green debt instruments — Part 2: Process for green loans
ISO 14030-3:2022	Environmental performance evaluation — Green debt instruments — Part 3: Taxonomy
ISO 14030-4:2021	Environmental performance evaluation — Green debt instruments — Part 4: Verification programme requirements
ISO 14031:2021	Environmental management — Environmental performance evaluation — Guidelines
ISO 14033:2019	Environmental management — Quantitative environmental information — Guidelines and examples
ISO 14034:2016	Environmental management — Environmental technology verification (ETV)
ISO 14063:2020	Environmental management — Environmental communication — Guidelines and examples
ISO 14100:2022	Guidance on environmental criteria for projects, assets and activities to support the development of green finance

8.5 GREENHOUSE GAS AND CLIMATE CHANGE MANAGEMENT AND RELATED ACTIVITIES

number	**title**
IWA 42:2022	Net zero guidelines
ISO 14064-1:2018	Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals
ISO 14064-2:2019	Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements
ISO 14064-3:2019	Greenhouse gases — Part 3: Specification with guidance for the verification and validation of greenhouse gas statements
ISO 14065:2020	General principles and requirements for bodies validating and verifying environmental information
ISO 14066:2011	Greenhouse gases — Competence requirements for greenhouse gas validation teams and verification teams

ISO 14067:2018	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification
ISO/TR 14069:2013	Greenhouse gases — Quantification and reporting of greenhouse gas emissions for organizations — Guidance for the application of ISO 14064-1
ISO 14080:2018	Greenhouse gas management and related activities — Framework and principles for methodologies on climate actions
ISO 14083:2023	Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations
ISO 14090:2019	Adaptation to climate change — Principles, requirements and guidelines
ISO 14091:2021	Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment
ISO/TS 14092:2020	Adaptation to climate change — Requirements and guidance on adaptation planning for local governments and communities
ISO 14093:2022	Mechanism for financing local adaptation to climate change — Performance-based climate resilience grants — Requirements and guidelines
ISO 14097:2021	Greenhouse gas management and related activities — Framework including principles and requirements for assessing and reporting investments and financing activities related to climate change
ISO 19694-1:2021	Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects

8.6 LIFE CYCLE ASSESSMENT

number	**title**
ISO 14040:2006	Environmental management — Life cycle assessment — Principles and framework
ISO 14044:2006	Environmental management — Life cycle assessment — Requirements and guidelines
ISO 14045:2012	Environmental management — Eco-efficiency assessment of product systems — Principles, requirements and guidelines
ISO 14046:2014	Environmental management — Water footprint — Principles, requirements and guidelines
ISO/TR 14047:2012	Environmental management — Life cycle assessment — Illustrative examples on how to apply ISO 14044 to impact assessment situations
ISO/TS 14048:2002	Environmental management — Life cycle assessment — Data documentation format

ISO/TR 14049:2012	Environmental management — Life cycle assessment — Illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis
ISO 14055-1:2017	Environmental management — Guidelines for establishing good practices for combatting land degradation and desertification — Part 1: Good practices framework
ISO/TR 14055-2:2022	Environmental management — Guidelines for establishing good practices for combatting land degradation and desertification — Part 2: Regional case studies
ISO/TS 14071:2014	Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006
ISO/TS 14072:2014	Environmental management — Life cycle assessment — Requirements and guidelines for organizational life cycle assessment
ISO/TR 14073:2017	Environmental management — Water footprint — Illustrative examples on how to apply ISO 14046
ISO/TS 14074:2022	Environmental management — Life cycle assessment — Principles, requirements and guidelines for normalization, weighting and interpretation

These standards provide guidance on different aspects of environmental management, such as environmental performance evaluation, life cycle assessment, carbon footprint, sustainable procurement, and more.

9 LIFE CYCLE ASSESSMENT

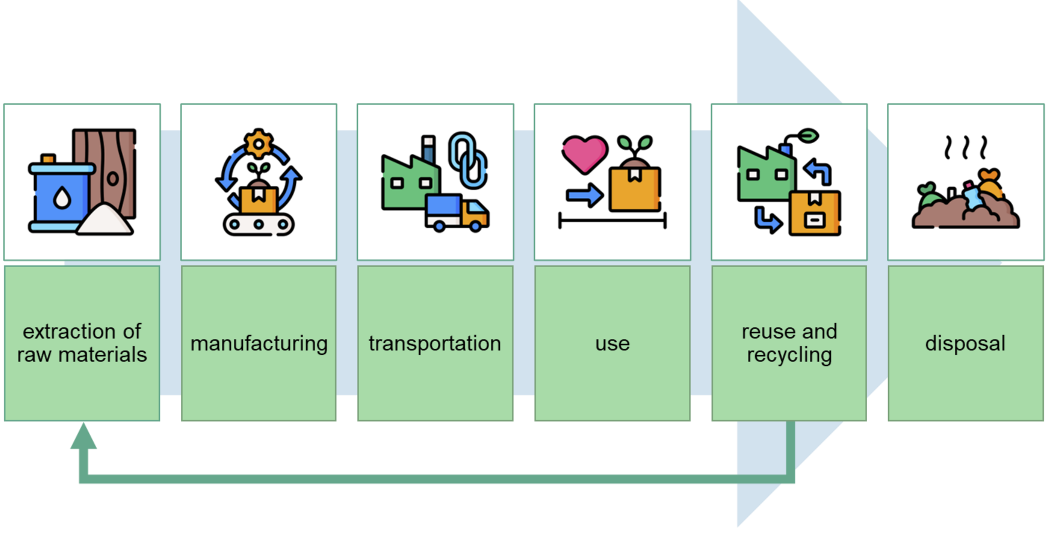
Life cycle analysis is a method used to evaluate the environmental impact of a product throughout its entire life cycle. The goal is to identify potential environmental impacts associated with a product, and to find ways to reduce or mitigate them. This is done by examining the product and its associated processes in terms of their environmental impact, such as their use of resources and energy, their contribution to climate change, and their effects on human health and the natural environment.

9-1. Figure: 'car factory under the magnifying glass' (made with Image Creator powered by DALL·E)

To conduct a life cycle analysis, the product and all its associated processes are broken down into smaller life cycle stages. These stages might include the extraction of raw materials, manufacturing, transportation, reuse and recycling, and disposal. By examining each stage in detail, it is possible to determine the environmental impacts associated with that stage, and to identify areas where improvements can be made.

The ultimate goal of life cycle analysis is to reduce the environmental impact of a product while still meeting its intended purpose. This can be achieved through the use of more sustainable materials and manufacturing processes, the reduction of waste and energy use, and the implementation of recycling and reuse programs. By conducting life cycle analyses of products, companies and organizations can make informed decisions that promote sustainability and environmental responsibility.

9.1 STAGES OF A LIFECYCLE



9-2. Figure: Stages of a full lifecycle.

9.1.1 EXTRACTION OF RAW MATERIALS

In this step, raw materials including minerals, metals, and fuels are acquired from natural resources like mines, forests, and oil fields. This stage's negative effects on the environment include carbon emissions, soil erosion, water pollution, and habitat degradation.

9-3. Figure: 'extraction of raw materials and manufacturing of goods' (made with Image Creator powered by DALL·E)

9.1.2 MANUFACTURING

During this phase, raw materials are refined and turned into finished goods using a variety of manufacturing techniques, including casting, molding, machining, and assembly. This stage has an impact on the environment in terms of energy use, water use, greenhouse gas emissions, and the production of hazardous waste.

9.1.3 TRANSPORTATION

During this phase, materials are transported between various facilities, including factories, warehouses, and distribution centers, alongside finished goods, waste, and finished products. This stage has an impact on the environment in terms of energy use, air pollution, and greenhouse gas emissions.

9-4. Figure: 'transportation of a product' (made with Image Creator powered by DALL·E)

9.1.4 USE

The product is being used by the customer at this point, and upkeep and repairs are necessary to assure its continuous functionality. This stage's environmental effects include energy use, water use, and waste production.

9.1.5 REUSE AND RECYCLING

When a product reaches the end of its useful life, this stage comprises recycling or reusing it. This stage has a positive impact on the environment since it uses fewer resources, uses less energy, and produces fewer waste products. From this step, you can link back to the raw material consumption step, as secondary raw materials can be extracted here.

9-5. Figure: 'recycling of glass' (made with Image Creator powered by DALL·E)

9.1.6 DISPOSAL

The product or any of its components are finally disposed of in landfills, incinerators, or other waste management facilities. This stage's effects on the environment could include polluting soil and water, and emitting greenhouse gases.

9.2 TERMS AND DEFINITIONS FROM ISO 14040:2006

To ensure consistent and standardized application of LCA, a set of terms and definitions have been developed and stated in the ISO 14040:2006 standard.

life cycle:

consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal

life cycle assessment (LCA):

compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

life cycle inventory analysis (LCI):

phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle

life cycle impact assessment (LCIA):

phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product

life cycle interpretation:

phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations

process:

set of interrelated or interacting activities that transforms inputs into outputs

elementary flow:

material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation

energy flow:

input to or output from a unit process or product system, quantified in energy units

raw material:

primary or secondary material that is used to produce a product *data quality:*

characteristics of data that relate to their ability to satisfy stated requirements

functional unit:

quantified performance of a product system for use as a reference unit

input:

product, material or energy flow that enters a unit process

intermediate flow:

product, material or energy flow occurring between unit processes of the product system being studied

intermediate product:

output from a unit process that is input to other unit processes that require further transformation within the system

output:

product, material or energy flow that leaves a unit process

reference flow:

measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit

releases:

emissions to air and discharges to water and soil

system boundary:

set of criteria specifying which unit processes are part of a product system

impact category:

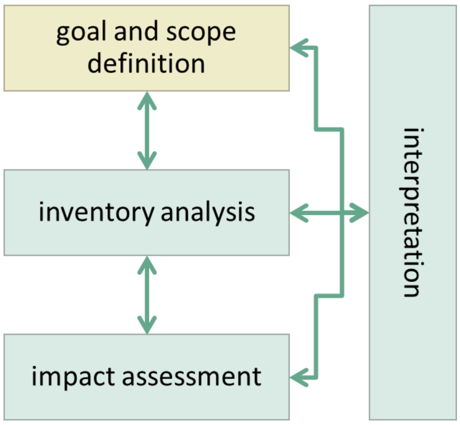
class representing environmental issues of concern to which life cycle inventory analysis results may be assigned

A clear understanding of these terms and their definitions is critical to the accurate and effective use of LCA in decision-making related to sustainability and environmental impact.

9.3 STAGES OF AN LCA

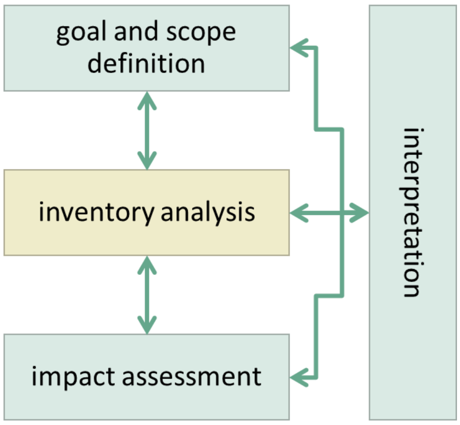
According to the ISO 14040:2006 standard, there are four mane stages while conducting an LCA: goal and scope definition, inventory analysis, impact assessment and interpretation.

9.3.1 GOAL AND SCOPE DEFINITION



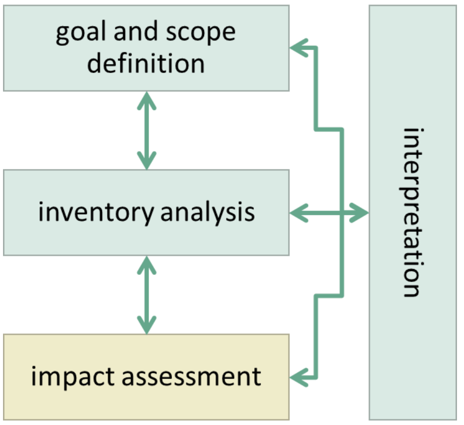
The goal and scope definition is the first stage of a life cycle assessment (LCA), where the purpose, boundaries, and focus of the LCA study are established. The goal statement specifies the intended use of the LCA study, and the scope defines the system boundary of the study. The scope includes the functional unit, which is a measurable reference quantity of the product or service under study, and the system boundary, which determines the life cycle stages to be considered in the assessment. The goal and scope definition stage is critical in setting the direction of the LCA study, as it establishes the foundation for subsequent stages such as inventory analysis, impact assessment, and interpretation. It also provides a basis for comparing different products or services, identifying environmental hotspots, and informing decision-making processes. A well-defined goal and scope statement is essential for ensuring that the LCA study is relevant, transparent, and robust.

9.3.2 INVENTORY ANALYSIS



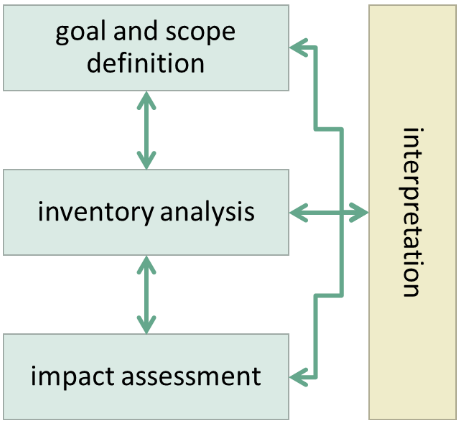
The inventory analysis is the second stage of a life cycle assessment (LCA), where data on the inputs and outputs of the system under study are collected and quantified. The inventory analysis involves identifying the life cycle stages, activities, and inputs and outputs associated with the product or service under study. The inputs and outputs are then quantified in terms of mass, energy, and other relevant parameters. The results of the inventory analysis are typically presented in the form of a life cycle inventory (LCI), which provides a comprehensive list of the environmental inputs and outputs associated with the product or service. The LCI is a critical component of the LCA study, as it provides the basis for subsequent stages such as impact assessment and interpretation. The inventory analysis requires careful consideration of the system boundary, data quality, and allocation methods, among other factors. A well-executed inventory analysis is essential for ensuring the accuracy and completeness of the LCA study and for providing valuable insights into the environmental performance of the product or service under study.

9.3.3 IMPACT ASSESSMENT



The impact assessment is the third stage of a life cycle assessment (LCA), where the environmental impacts of the product or service under study are evaluated. The impact assessment involves categorizing and characterizing the inventory data obtained in the inventory analysis stage into potential environmental impacts, such as global warming, acidification, or eutrophication. The characterization factors are used to quantify the magnitude and significance of each environmental impact category, based on the inventory data. The results of the impact assessment are typically presented in the form of an impact matrix or profile, which provides a comprehensive picture of the environmental performance of the product or service. The impact assessment is a crucial stage of the LCA study, as it provides insights into the relative significance of the different environmental impacts associated with the product or service. The impact assessment stage also requires careful consideration of data quality, uncertainty, and other factors, as it directly influences the results and conclusions of the LCA study. A well-executed impact assessment is essential for ensuring the accuracy and robustness of the LCA study and for informing decision-making processes related to product or service design, improvement, or optimization.

9.3.4 INTERPRETATION



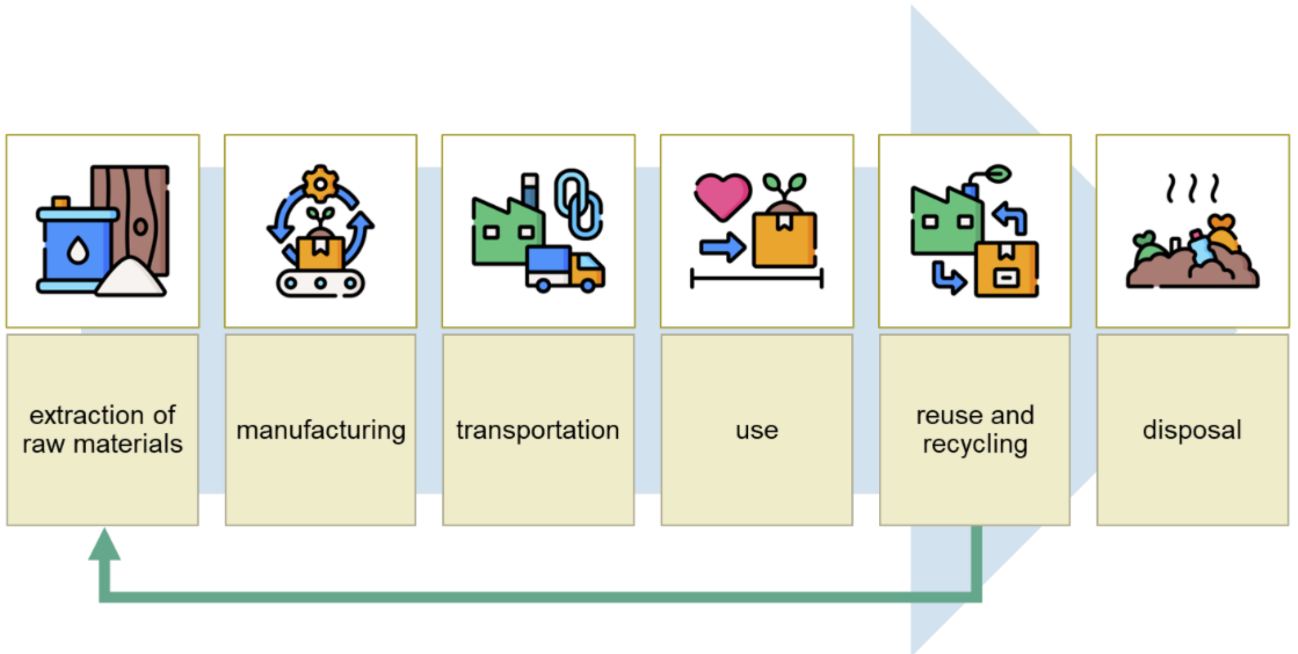
The interpretation is the final stage of a life cycle assessment (LCA), where the results of the LCA study are analyzed and communicated to stakeholders. The interpretation involves evaluating the findings of the inventory analysis and impact assessment stages in the context of the goal and scope of the study, and drawing conclusions and recommendations based on the results. The interpretation stage is critical in communicating the results of the LCA study to stakeholders in a clear and meaningful way, and in facilitating decision-making processes related to product or service design, improvement, or optimization. The interpretation stage also requires consideration of data quality, uncertainty, and sensitivity analysis, as well as the values and preferences of stakeholders. A well-executed interpretation is essential for ensuring that the results of the LCA study are relevant, transparent, and actionable. It provides a basis for comparing the environmental performance of different products or services, identifying areas for improvement, and supporting sustainability initiatives.

9.4 MODELS IN LCA

In order to assess a product or service's environmental impact throughout the course of its full life cycle, from the extraction of raw materials to disposal, life cycle assessment models are utilized. Various models, such as cradle-to-grave, cradle-to-gate, gate-to-gate, gate-to-grave, and cradle-to-cradle models, can be used depending on the goal and scope of the assessment. These models offer a framework for assessing the environmental impact of a good or service and can help in the decision-making process for resource efficiency, waste reduction, and environmentally conscious product design. The individual demands, objectives, and scope of the study must all be taken into consideration when choosing a suitable LCA model.

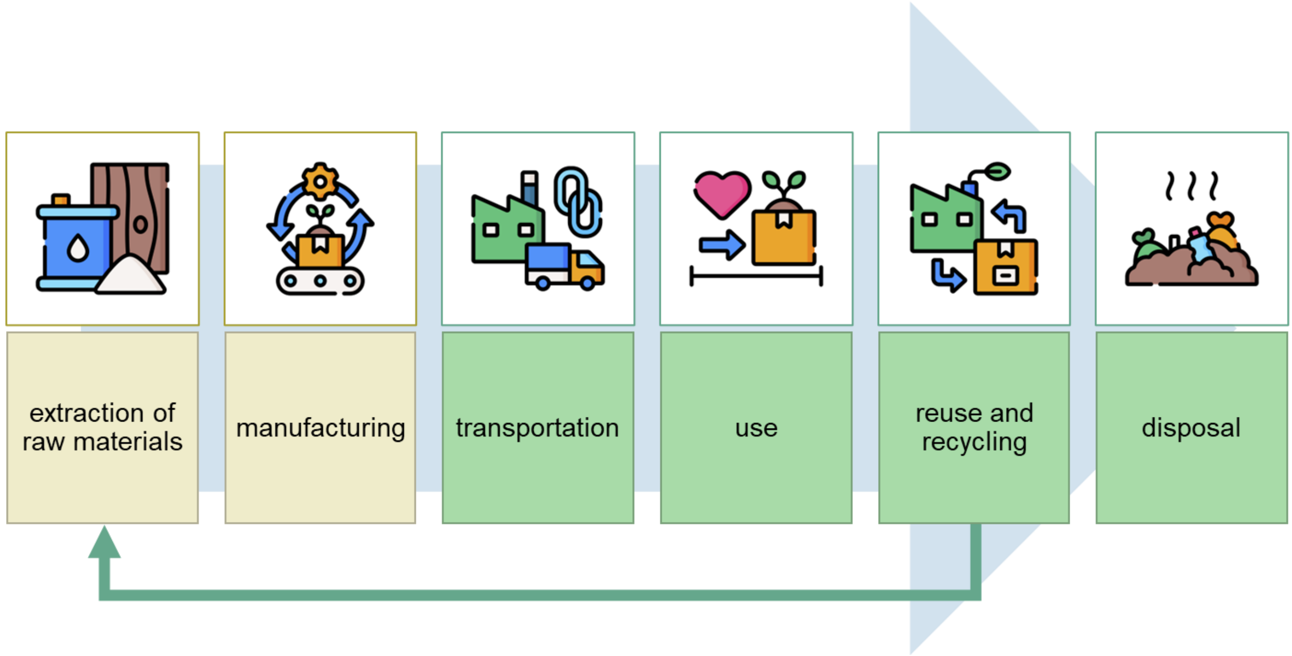
9.4.1 CRADLE TO GRAVE

Cradle-to-grave is a model used in life cycle assessments (LCAs) to analyze the environmental impacts of a product or service from its inception to its ultimate disposal or recycling. The cradle-to-grave model considers all stages of the product's life cycle, including the extraction of raw materials, manufacturing, distribution, use, and end-of-life management. This approach allows for a comprehensive assessment of the environmental impact of the product or service, including carbon footprint, water consumption, and waste generation. By considering the entire life cycle, the cradle-to-grave model provides valuable insights into potential areas for improvement, such as eco-design, waste reduction, and resource efficiency. The cradle-to-grave model is widely used in LCAs to inform decision-making processes related to sustainability and resource management, and to promote sustainable product and service design.



9-6. Figure: The 'cradle to grave' LCA model

9.4.2 CRADLE TO GATE

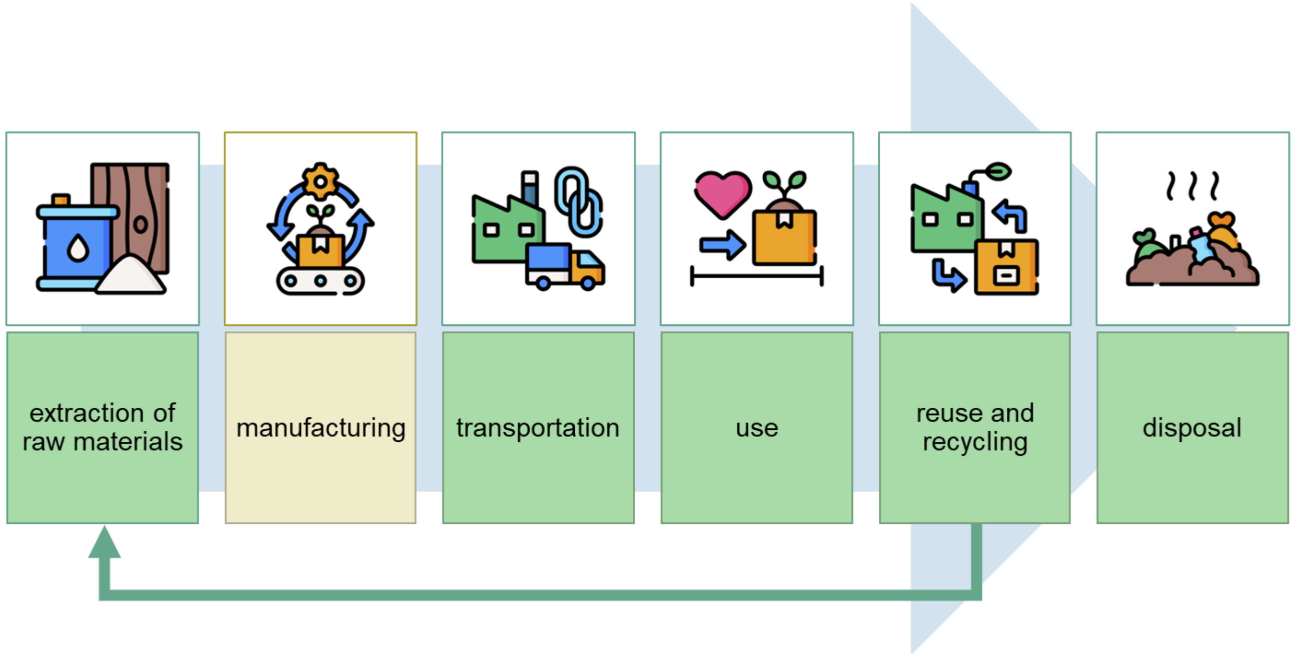


9-7. Figure: The 'cradle to gate' LCA model

Cradle-to-gate is a model used in life cycle assessments (LCAs) to evaluate the environmental impact of a product or service from the extraction of raw materials to the point of leaving the factory gate, without considering the use or end-of-life stages. This model is often used for comparing the environmental performance of different manufacturing processes or raw materials. The cradle-to-gate approach provides a more focused analysis of the upstream stages of a product's life cycle, allowing for more detailed assessments of the environmental impact of manufacturing processes and supply chains. By excluding the use and end-of-life stages, the cradle-to-gate model can be used to identify areas for improvement in the early stages of product development, such as the selection of more sustainable raw materials or the optimization of manufacturing processes. The cradle-to-gate model is widely used in LCAs to inform decision-making processes related to product and process design, resource efficiency, and sustainability.

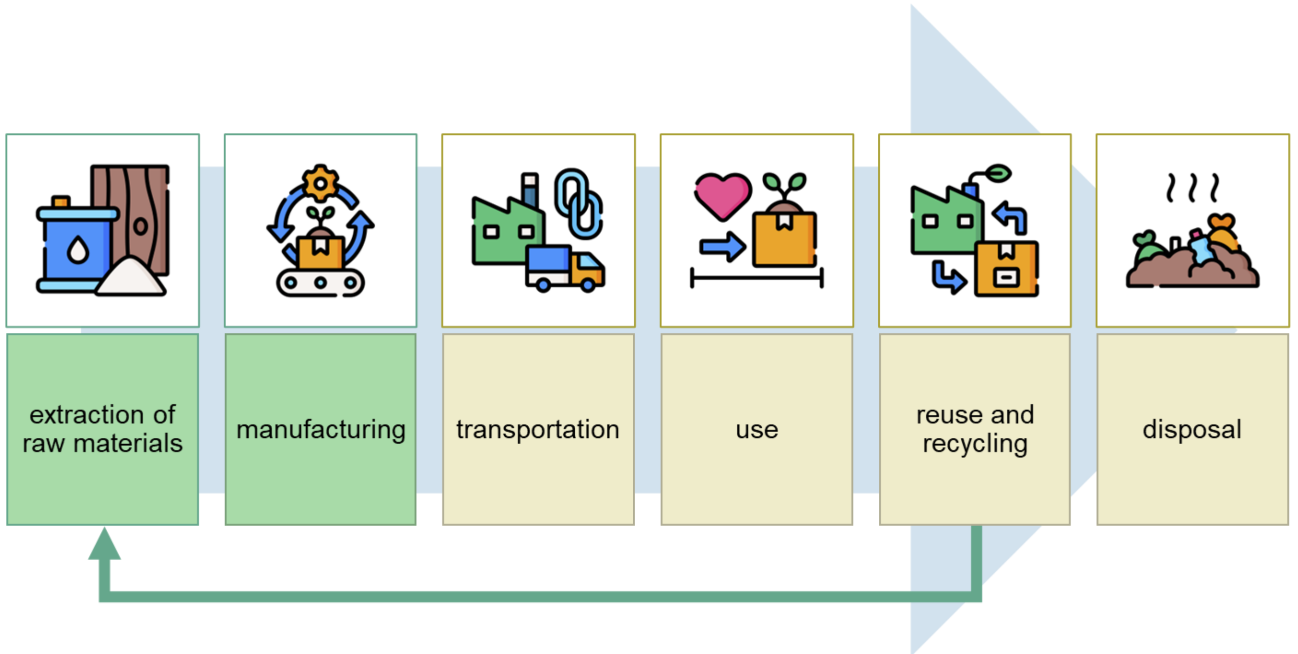
9.4.3 GATE TO GATE

Gate-to-gate is a model used in life cycle assessments (LCAs) that evaluates the environmental impact of a product or service from the point of entry to the factory gate to the point of exit, without considering the upstream or downstream stages of the life cycle. The gate-to-gate approach allows for a focused analysis of the specific processes and activities that occur within the factory gate boundaries, such as manufacturing or processing. This model is useful for comparing the environmental performance of different facilities or production lines within the same industry or for assessing the environmental impact of specific operations, such as energy consumption or waste generation. The gate-to-gate model provides valuable insights into the environmental impact of specific activities or processes and can inform decision-making processes related to operational efficiency, environmental management, and sustainability.



9-8. Figure: The 'gate to gate' LCA model

9.4.4 GATE TO GRAVE



9-9. Figure: The 'gate to grave' LCA model

Gate-to-grave is a model used in life cycle assessments (LCAs) to evaluate the environmental impact of a product or service from the point of leaving the factory gate to the end-of-life stage, without considering the upstream stages of the life cycle. This model provides a detailed analysis of the downstream stages of the product or service life cycle, including distribution, use, and end-of-life management. The gate-to-grave approach allows for a focused analysis of the specific processes and activities that occur after the product or service leaves the factory gate, such as transportation, energy consumption, and waste management. This model is useful for identifying opportunities to reduce the environmental impact of product distribution, use, and end-of-life management. The gate-to-grave model can inform decision-making processes related to sustainable product design, waste reduction, and resource efficiency. However, it does not provide a complete picture of the environmental impact of the entire life cycle, and thus should be used in conjunction with other LCA models to ensure a comprehensive analysis of the environmental impact of the product or service.

9.4.5 CRADLE TO CRADLE

Cradle-to-cradle is a model used in life cycle assessments (LCAs) that emphasizes the design of products and materials with the intention of creating a closed-loop system where waste is eliminated, and materials can be continuously reused or recycled. This approach focuses on the use of renewable, non-toxic, and biodegradable materials and energy sources to minimize environmental impact. In the cradle-to-cradle model, products are designed to be disassembled and recycled or reused at the end of their useful life. This approach promotes a regenerative economy where resources are used efficiently, and waste is eliminated. The cradle-to-cradle model has gained popularity in recent years as a way to create a more sustainable future and reduce environmental degradation. It can be used in conjunction with other LCA models to ensure that products are designed and produced with sustainability and environmental impact in mind throughout their entire life cycle. The cradle-to-cradle approach provides a holistic solution to the challenges of sustainability by addressing the entire life cycle of a product and promoting closed-loop systems that maximize resource efficiency and minimize waste.

9.5 LEVELS IN LCA

There are three levels of Life Cycle Assessment (LCA), also known as the "three-tiered approach." These levels are based on the level of detail and complexity of the analysis and the amount of data required.

9.5.1 CONCEPTUAL LCA

A conceptual LCA, which is the first level, is where the parameters and scope of the study are established. At this step, a qualitative evaluation is carried out to pinpoint the environmental problems connected to the good or service and establish the pertinent life cycle stages that will be taken into account in the analysis. The conceptual LCA also entails determining the functional unit, which is the product or service's measured performance that will be used as the basis for comparison. Additionally, data requirements and sources are determined, and generalizations about the procedures and materials used are developed. Although the conceptual LCA does not entail collecting extensive data or quantifying environmental impacts, it lays the groundwork for later stages of the LCA and ensures that the study is relevant and focused.

9.5.2 SIMPLIFIED LCA

By adding more particular data and a condensed model of the product or service life cycle, the second level of life cycle assessment (LCA), also known as the simplified LCA, improves upon the conceptual LCA. At this level, information is gathered and arranged into a spreadsheet or database according to the inputs and outputs of each life cycle step. Through the use of predetermined impact categories, such as potential for global warming or water use, these data are used to quantify the environmental effects of the good or service. In the simplified LCA, the sensitivity of the outcomes to changes in assumptions, data quality, and modeling techniques is also identified and examined. Despite being less difficult than a full LCA, the simplified LCA still necessitates careful analysis of the assumptions and data used and can offer insightful information about the environmental effects of the good or service. The outcomes of a condensed LCA can also be used to pinpoint areas where a full LCA might require more thorough data collection or modeling.

9.5.3 DETAILED LCA

The third level of the Life Cycle Assessment (LCA), commonly referred to as the detailed LCA, is the most thorough and time-consuming level of examination. At this level, the full life cycle of the good or service is meticulously modeled, down to the inputs and outputs at each stage, packaging, end-of-life management, and transportation. Surveys, site visits, and other approaches are used to gather data, which is then processed and examined using specialized LCA software. The extensive LCA provides a thorough understanding of the environmental implications of the good or service by including a full inventory analysis, impact assessment, and result interpretation. Although the complete LCA offers the most precise and thorough study, it demands a considerable investment of time, money, and knowledge. It is frequently employed for items that are extremely complex or contentious, or when particular environmental or regulatory standards must be met. The outcomes of a thorough LCA can be used to guide decisions about product procurement, supply chain management, and possibilities for improvement.

9.6 LCA WITH MANUAL METHODS

Pen and paper or a spreadsheet tool like Microsoft Excel can be used for LCA. The procedure typically entails gathering and organizing information on the system or product being studied, calculating the environmental effects at each stage of its life cycle, and then interpreting and presenting the findings.

The Eco-Indicator approach is based on a number of environmental effect categories, such as eutrophication, acidification, ozone layer depletion, toxicity to humans and the environment, and eutrophication. The method assigns environmental damage scores to the inputs and outputs of the life cycle stages in order to quantify the potential effects of a good or service on these categories.

An Eco-Indicator score, which reflects the overall environmental impact of the good or service, is used to present the results. The approach also offers an analysis of the findings, highlighting the most important environmental effects and offering mitigation strategies.

In order to evaluate the environmental performance of goods and services and to support decision-making for sustainable development, the method is widely utilized in business, government, and academia.

Although the Eco-Indicator approach is used in both the Eco-Indicator 99 and Eco-Indicator 95, there are notable changes between the two versions. The Eco-Indicator 95 was created in the middle of the 1990s, while the Eco-Indicator 99 was created in 1999. With a number of upgrades and improvements, the Eco-Indicator 99 is thought to be an improvement over the Eco-Indicator 95.

One key difference between the two versions is the set of impact categories used. The Eco-Indicator 95 includes five impact categories: climate change, ozone depletion, acidification, eutrophication, and human toxicity. The Eco-Indicator 99, on the other hand, includes a more comprehensive set of impact categories, such as resource depletion, ionizing radiation, and photochemical ozone creation.

The characterization criteria employed to quantify the effects of various inputs and outputs in the life cycle stages also varied. Updated characterisation parameters for the Eco-Indicator 99 have been developed, taking into consideration more contemporary scientific data and techniques.

A more thorough analysis of the effects of energy production is also included, along with distinct characterisation variables for various types of electricity production, such as nuclear and fossil fuel-based power generation.

9.7 LCA USING A SOFTWARE

A Life Cycle Assessment can be carried out using a variety of software tools. The objectives and scope of the LCA, the accessibility of data and resources, and the target audience for the assessment will all influence the tool selection.

<u>SimaPro</u>

It has a large database of environmental impacts and materials, and users can customize the database to suit their specific needs.

<u>OpenLCA</u>

It is an open-source software, which means that it is free to use and can be modified by users.

<u>GaBi</u>

This is a software tool that allows users to model and analyze the environmental impacts of products and processes. It includes a large database of materials and environmental impacts.

Umberto

This is a software tool that allows users to model and analyze material and energy flows in production processes. It includes a variety of modules for different types of analyses, including LCA.

Brightway2

This is an open-source LCA software tool that allows users to model and analyze the environmental impacts of products and processes. It includes a database of environmental impacts and materials.

Ecoinvent

This is a comprehensive database that contains data on a wide range of environmental impacts and material inputs and outputs. It is often used in conjunction with other software tools.

Specialized software tools like SimaPro, OpenLCA, and GaBi are often preferred due to their flexibility, accuracy, and ability to handle large amounts of data. However, open-source tools like Umberto and Brightway2 can also be useful, particularly for smaller-scale LCAs or when data is limited.

10 IMPACT ASSESSMENT METHODS

The impact categories in the results of an LCA depend on the goals and scope of the study, as well as the chosen impact assessment method. There are several commonly used impact assessment methods, each with its own set of impact categories. It's important to note that the popularity and usage of impact assessment methods may vary depending on the region, industry, and specific requirements of the study. Different organizations and practitioners may adopt variations or combinations of these methods to suit their needs.

Some of the most widely used impact assessment methods and categories are the following.

10.1 ECO-INDICATOR 99

Eco-indicator 99: Developed by PRé Consultants, this method assesses environmental impacts in multiple categories, including climate change, ozone depletion, human toxicity, and resource depletion.

This method is widely used because it provides a comprehensive assessment of environmental impacts across multiple categories. It is suitable for evaluating the sustainability of products, processes, and systems in various industries.

The Eco-indicator 99 method includes the following midpoint damage categories:

- Climate Change
- Ozone Layer Depletion
- Acidification/Eutrophication (Combined)
- Carcinogenic
- Respiratory Organic
- Respiratory Inorganic
- Ionizing Radiation
- Ecotoxicity
- Land-Use
- Mineral Resources
- Fossil Resources

The Eco-indicator 99 method includes the following endpoint damage categories:

- Damage to resources
- Damage to ecosystems
- Damage to human health

These impact categories cover a wide range of environmental and human health impacts, allowing for a comprehensive assessment of the potential burdens associated with a product, process, or system. The Eco-indicator 99 method provides a full view of various environmental stressors and can be used to evaluate sustainability and make informed decisions regarding resource consumption and emissions.

10.2 RECIPE

ReCiPe (Relevance Calculation and Impact assessment of environmental indicators) is a comprehensive impact assessment method and is preferred for its broad coverage of impact categories, making it suitable for assessing the overall environmental performance of products and processes. It is often used in policy-making, eco-labeling, and sustainability reporting.

The method includes the following impact categories:

- Global Warming Potential
- Stratospheric Ozone Depletion
- Particulate Matter Formation
- Tropospheric Ozone Formation (human)
- Tropospheric Ozone Formation (eco)
- Freshwater Ecotoxicity
- Freshwater Eutrophication
- Marine Ecotoxicity
- Marine Eutrophication
- Human Toxicity (cancer)
- Human Toxicity (non-cancer)
- Ionizing Radiation
- Terrestrial Acidification
- Terrestrial Ecotoxicity
- Water Use
- Land Use
- Fossil Depletion
- Mineral Depletion

It provides a holistic assessment of the potential environmental and health impacts associated with a product, process, or system, allowing for a thorough evaluation of sustainability and informed decision-making.

10.3 CML 2002

The CML (Centre for Environmental Science) 2002 method is suitable for evaluating the environmental performance of products and technologies in industries such as manufacturing and energy.

Here are the impact categories included in this method:

- Depletion Of Abiotic Resources
- Land Competition
- Climate Change
- Stratospheric Ozone Depletion
- Human Toxicity
- Freshwater Aquatic Ecotoxicity
- Marine Aquatic Ecotoxicity
- Terrestrial Ecotoxicity
- Photo-Oxidant Formation
- Acidification
- Eutrophication

This method assesses a broad range of environmental impacts, including those related to climate change, resource depletion, toxicity, and ecosystem impacts. They enable the evaluation of the potential environmental burdens associated with a product, process, or system in a comprehensive manner. The CML 2002 method was a predecessor to CML 2016 and provided a basis for impact assessment in LCA studies. CML 2016 builds upon the previous version and includes refinements and updates to improve the accuracy and relevance of impact assessment results.

10.4 TRACI

TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) is an impact assessment method developed by the US Environmental Protection Agency (EPA). It is commonly employed in the United States for assessing the environmental impacts of chemicals and industrial processes. It is particularly useful for evaluating human health and ecological risks associated with chemical substances.

This method includes 10 impact categories:

- Global Warming
- Acidification
- Eutrophication
- Ozone Depletion
- Ecotoxicity
- Human Respiratory Effects
- Human Carcinogenic Effects
- Human Non-carcinogenic Effects
- Smog formation
- Fossil Fuel Depletion

TRACI focuses on evaluating the environmental impacts associated with chemical substances and industrial processes. The method enables the assessment of potential impacts on human health, ecosystems, and resources, helping to inform decisions regarding chemical use, process optimization, and product design.

10.5 IMPACT 2002+

IMPACT 2002+ is a widely used method for life cycle impact assessment, particularly in Europe. It covers major environmental impact categories and is suitable for assessing products, technologies, and policies.

Midpoint Impacts Covered:

- Human Toxicity
- Respiratory Effects
- Ionizing Radiation
- Ozone Depletion
- Photochemical Oxidant Formation
- Aquatic Ecotoxicity
- Terrestrial Ecotoxicity
- Aquatic Eutrophication
- Terrestrial Eutrophication and Acidification
- Land Occupation
- Global Warming
- Non-Renewable Energy
- Mineral Extraction

Endpoint impacts covered:

- Human health
- Ecosystem quality
- Climate change (as life supporting function)
- Resources

Module_2

Life Cycle Assessment

Alexandra GYŐRFI

Introduction to life cycle assessment

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