European Institute of Innovation & Technology

EIT HEI Initiative

Innovation Capacity Building for Higher Education

Funded by the European Union

Life Cycle Assessment methodologies

Jukka Joutsenvaara

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3-RM

LAPIN AMK
Lapland University of Applied Sciences

Jukka Joutsenvaara
MSc
Project Specialist / Lecturer
New Industry
Lapland University of Applied Sciences

- I am a project specialist and a part time lecturer at Lapland UAS in New Industry expertise area. My research interests lie in the sector of raw materials connection to society and their role in the societal discussion. More traditional topics of courses held include material sciences from mechanical point of view as well as sustainable product design to management and leadership skills.
- My education includes BSc 2000 from Kemi-Tornio UAS, MSc 2008 Oulu University, teacher qualification and Technical assessor training from FINAS Finnish Accreditation Service
- I have over 15 years of academic and project research work as well as in laboratory services. My work roles have varied from project researcher to research team leader during my career.

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

LAPIN AMK
Lapland University of Applied Sciences

LIFE CYCLE ASSESSMENT

methodologies

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3-RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Contents

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3RM

Life Cycle Assessment methodologies

Life Cycle Assessment (LCA): Definition

LCA is a systematic analysis of environmental impact over the course of the entire life cycle of a product, material, process, or other measurable activity.

LCA models the environmental implications or consequences of the many interacting systems that make up industrial production.

Comprehensive list of terms related to Life Cycle analysis operations can be found, for instance at Life Cycle Initiative

See also LCA definition on European Platform on LCA

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Life Cycle Assessment (LCA): Different types of LCA

Conceptual LCA: very basic level looking at qualitative inventory, to create flow diagrams and understand, for example, which components have the highest relative environmental impact.

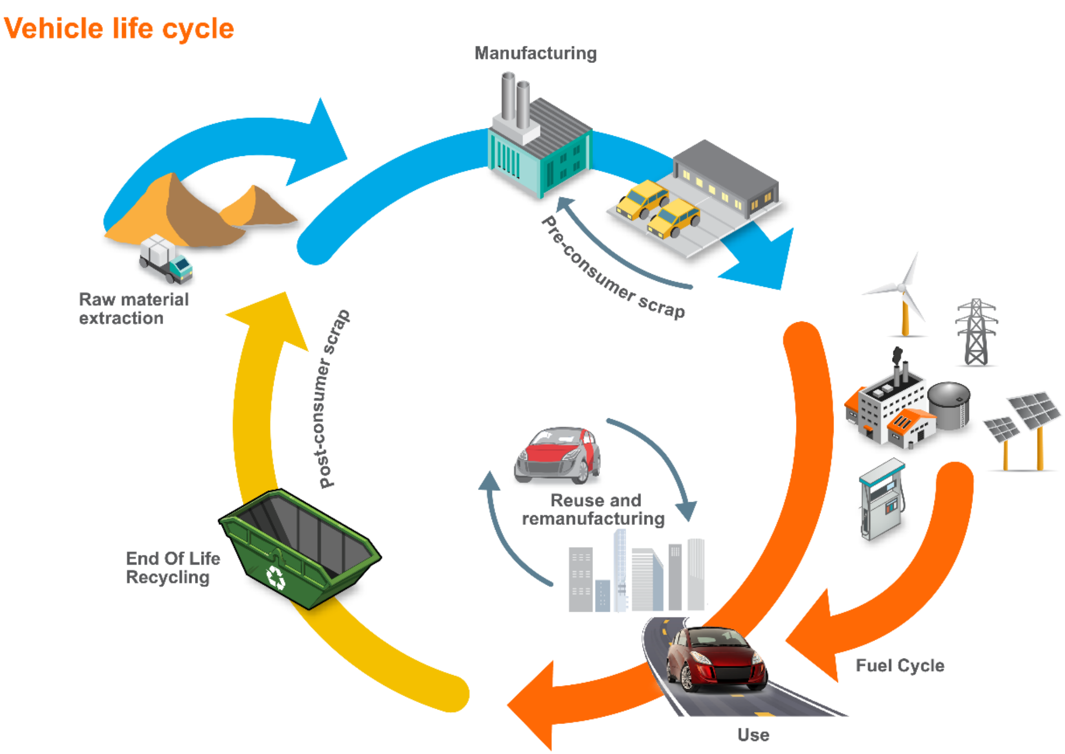
Simplified LCA: Basically a proper LCA but using more generic data and standard modules for energy production. A simplified assessment that focuses on the most important environmental aspects, and thoroughly assesses the reliability of the results.

Detailed LCA: The full process of in-depth data collection, highly specific to the product in question. CA is a systematic analysis of environmental impact over the course of the entire life cycle of a product, material, process, or other measurable activity.

Source: [Life Cycle Analysis (LCA) - A Complete Guide to LCAs (bpf.co.uk)]

eit European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies



- Life cycle of a product or service is overall span of that product or service from extraction of raw material to application by user and further to re-use, re-manufacturing (new additions), waste and recycling.

Source: www.ahssinsights.org

Life Cycle Assessment methodologies

Objectives of LCA: Product improvement

Identifying opportunities to improve the environmental aspects of products/services at various points in their life cycle

Example:

If transport sector is major contributor in pollution in a city, we can assess the options whether we should use any alternative fuel or more polluting vehicle should be used for transport.

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3RM

Life Cycle Assessment methodologies

Objectives of LCA: Decision making

Helps or improves decision making in industry, governmental or non- governmental organizations (strategic planning, priority setting, product and process design or redesign, service design, etc)

Example:

Requirement for Euro6 capable engines (instead of Euro 4) for ICE vehicle to improve air quality in European cities, or even further as in Paris 2030.

" [Paris plans to banish all but electric cars by 2030 | Reuters "]()

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3RM

Life Cycle Assessment methodologies

Objectives of LCA: Environmental planning

Selection of relevant indicators of environmental performance, including measurement techniques

Example:

Deciding which parameters should be used for assessing the negative impacts on human health such as particulate matters (size, amount, composition etc), CO etc.

Life Cycle Assessment methodologies

Objectives of LCA: Marketing

Marketing (e.g., an environmental claim, eco-labeling scheme or environmental product declarations).

Example:

- With widespread awareness about climate change, consumers prefer to use product with least negative impacts on environment.

- Companies may claim this for marketing backed up by LCA study.

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

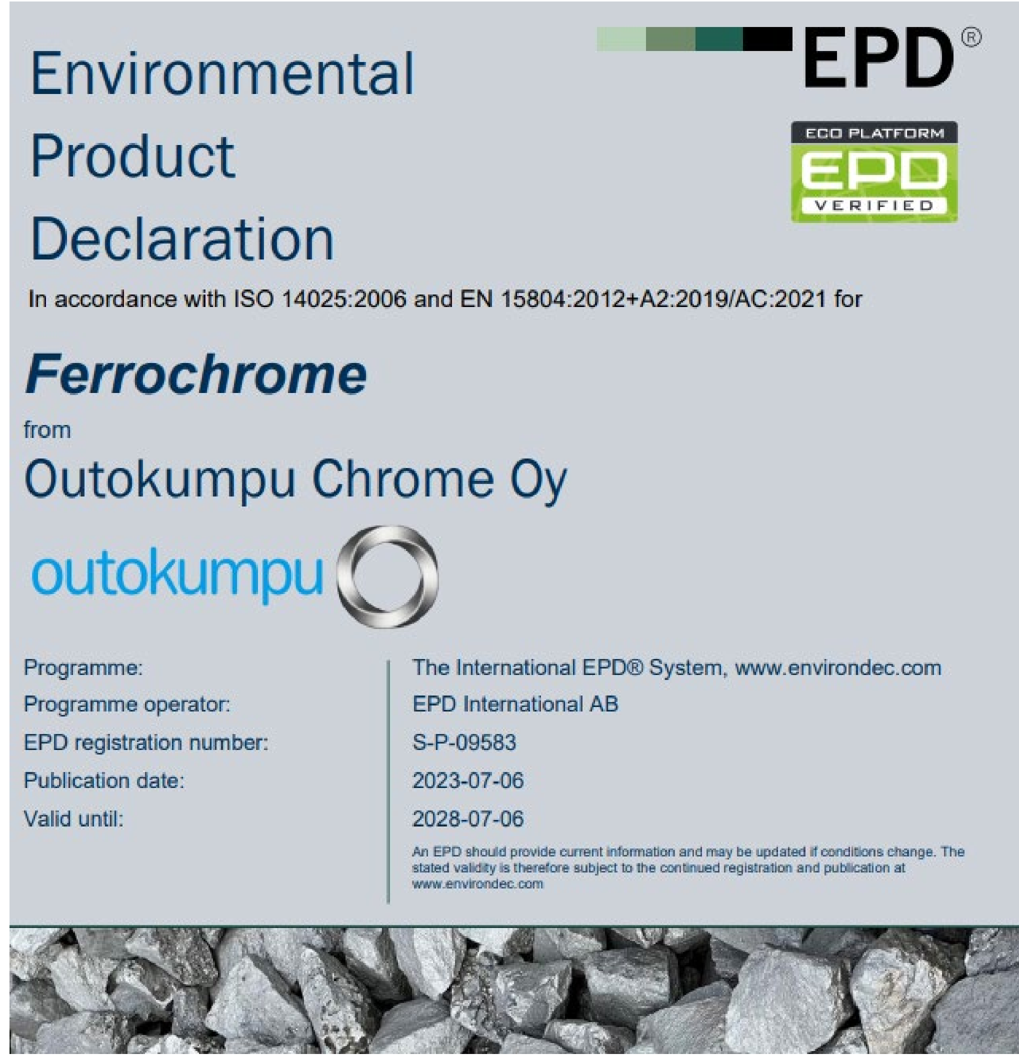
Objectives of LCA: Marketing

Example:

Outokumpu Ferrochrome EPD

Additional information on

[Environmental Product Declarations (EPDs)]



Environmental Product Declaration

EPD®

ECO PLATFORM EPD VERIFIED

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for

Ferrochrome

from

Outokumpu Chrome Oy

outokumpu

Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	S-P-09583
Publication date:	2023-07-06
Valid until:	2028-07-06

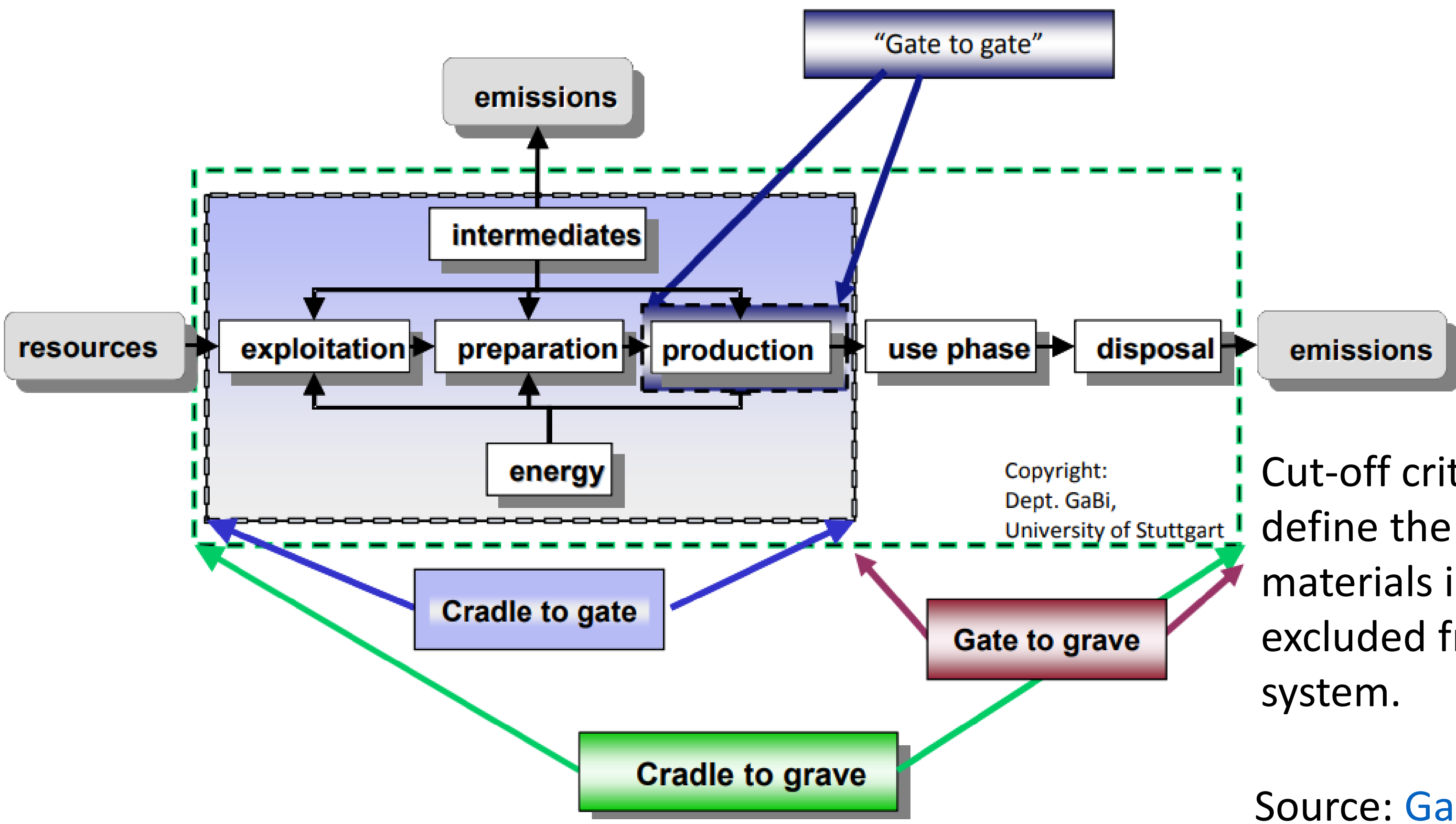
An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com

Source: [Data (environdec.com)]

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

System Boundaries



A system's boundaries are defined by cut-off criteria.

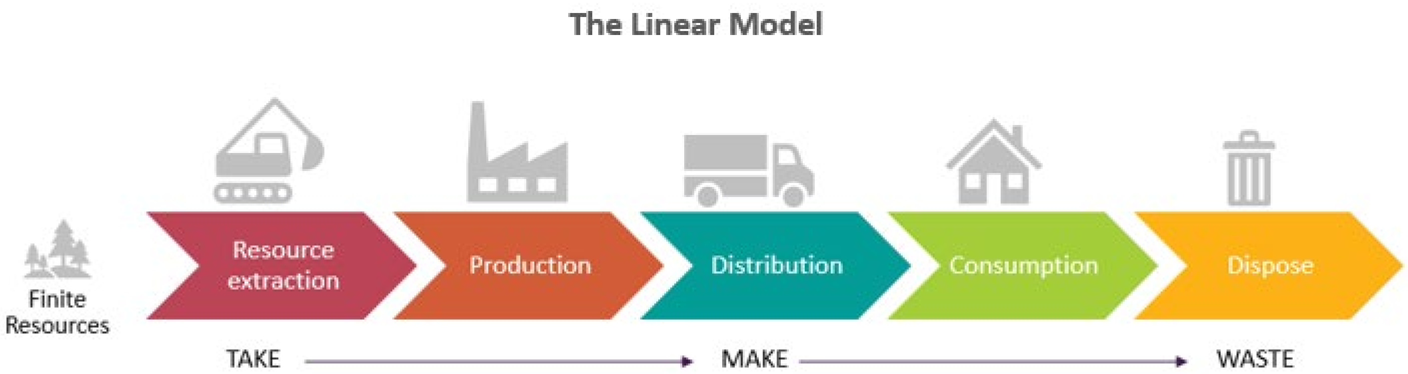
Cut-off criteria are used to define the parts and materials included in and excluded from the product system.

Source: [GaBi software guide]

Life Cycle Assessment methodologies

Linear production, “Old thinking way”

- If a product manufacturing process starts from raw material extraction from natural resources to waste generation is considered in a linear fashion, it is called linear production model. In life cycle analysis this is named <u>Cradle to Grave</u> and is one of the System boundaries



Source: [The Circular Economy - More than just recycling - BIL Investment Insights]

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Selection of System Boundaries for analysis

- Depending on the objective of study, system boundaries for LCA are defined. Often a combination of different cut-off criteria has to be used in order to define the system boundaries properly.
- These boundaries vary based on stages of life cycle considered for assessment
- There are four (five) main options to define the system boundaries used:
  - Cradle to Grave
  - Cradle to Gate
  - Gate to Grave
  - Gate to Gate
  - (Cradle to Cradle)

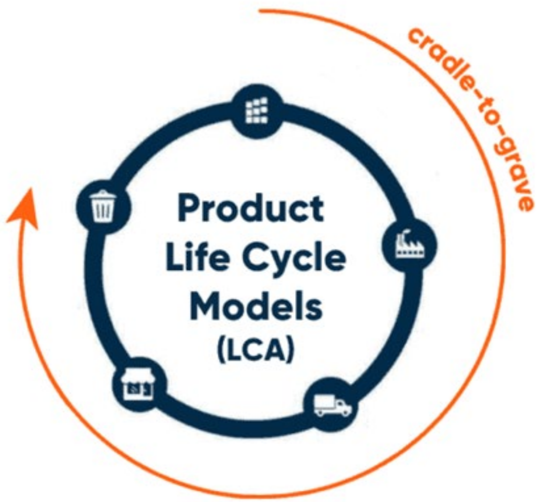
eit | European Institute of Innovation & Technology
Funded by the European Union
HEI4S3RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

System boundaries:

Cradle to grave (most common)



- If whole linear production model is considered for assessment during LCA from extraction of raw material, up to waste generation, it is called Cradle to grave approach of LCA.

Image source: https://ecochain.com/blog/cradle-to-grave-in-lca/

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Circular production process

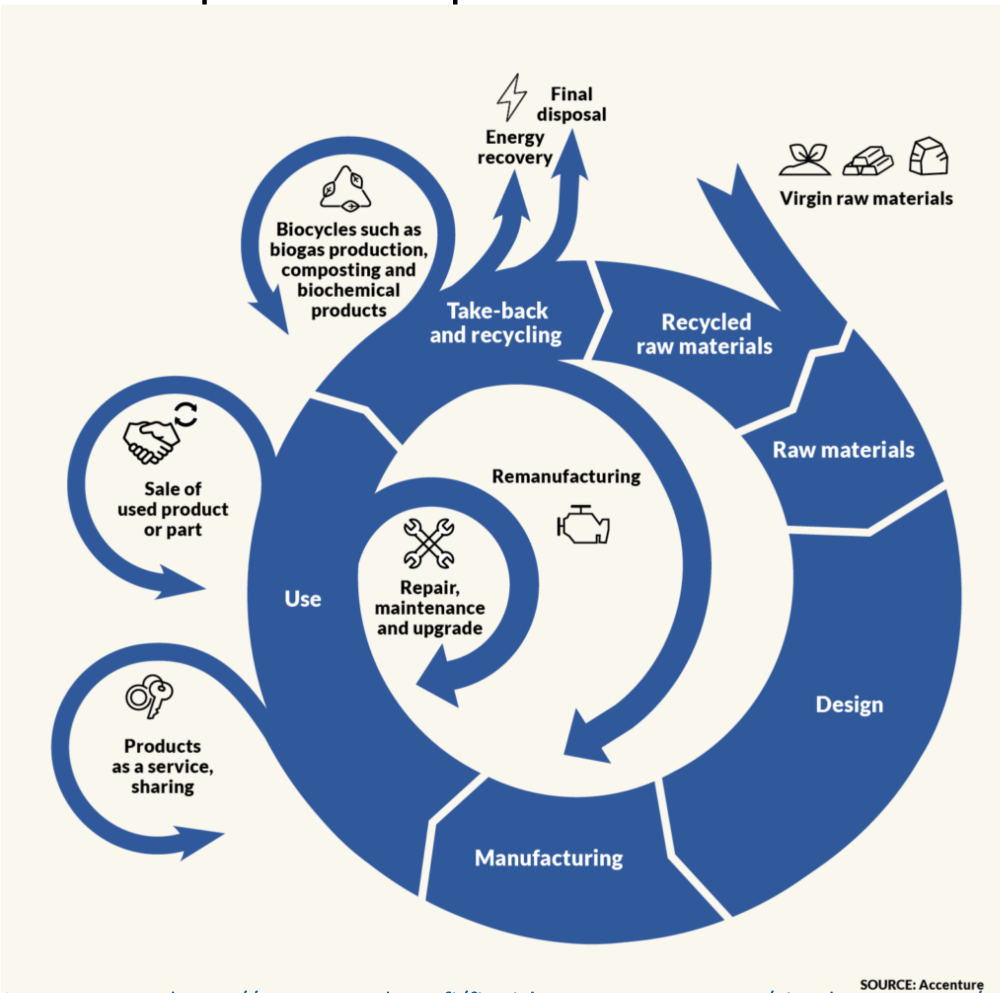


Image source: https://www.eastcham.fi/finnishwastemanagement/circular-economy/

- Production process including recovery of material after usage of product by user, is called circular production model
- This is more environment friendly process compared to linear model as resources will be used more than once, provided that it is economically viable in industrial scale.

Life Cycle Assessment methodologies

Circular production strategies development

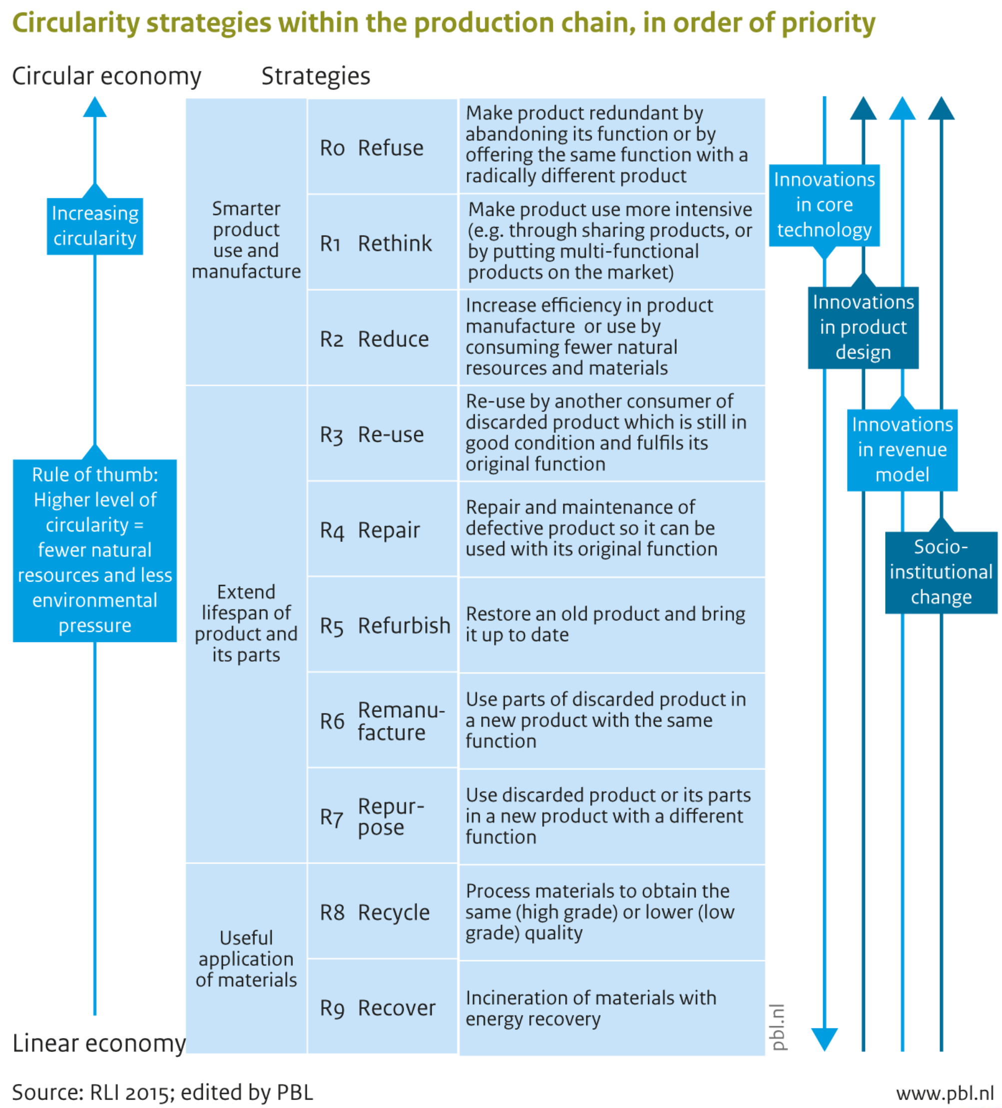


Image source: https://www.pbl.nl/en/publications/circular-economy-measuring-innovation-in-product-chains

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

System boundaries:

Cradle to Cradle (re-use, recycling; depends on the raw materials or resources used)

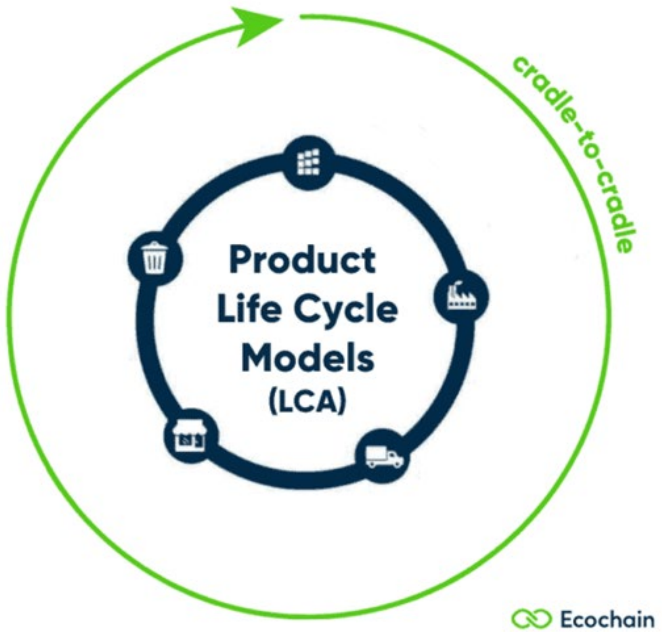


Image source: https://ecochain.com/blog/cradle-to-grave-in-lca/

- Life cycle assessment with the focus on the whole circular production model is called Cradle to Cradle LCA approach

- It is a variation of Cradle to Grave, adding along the waste stage a recycling, re-using, re-manufacturing etc. process that extends material life cycle as a re-usable resource for another/same product.

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Circular economy systems diagram

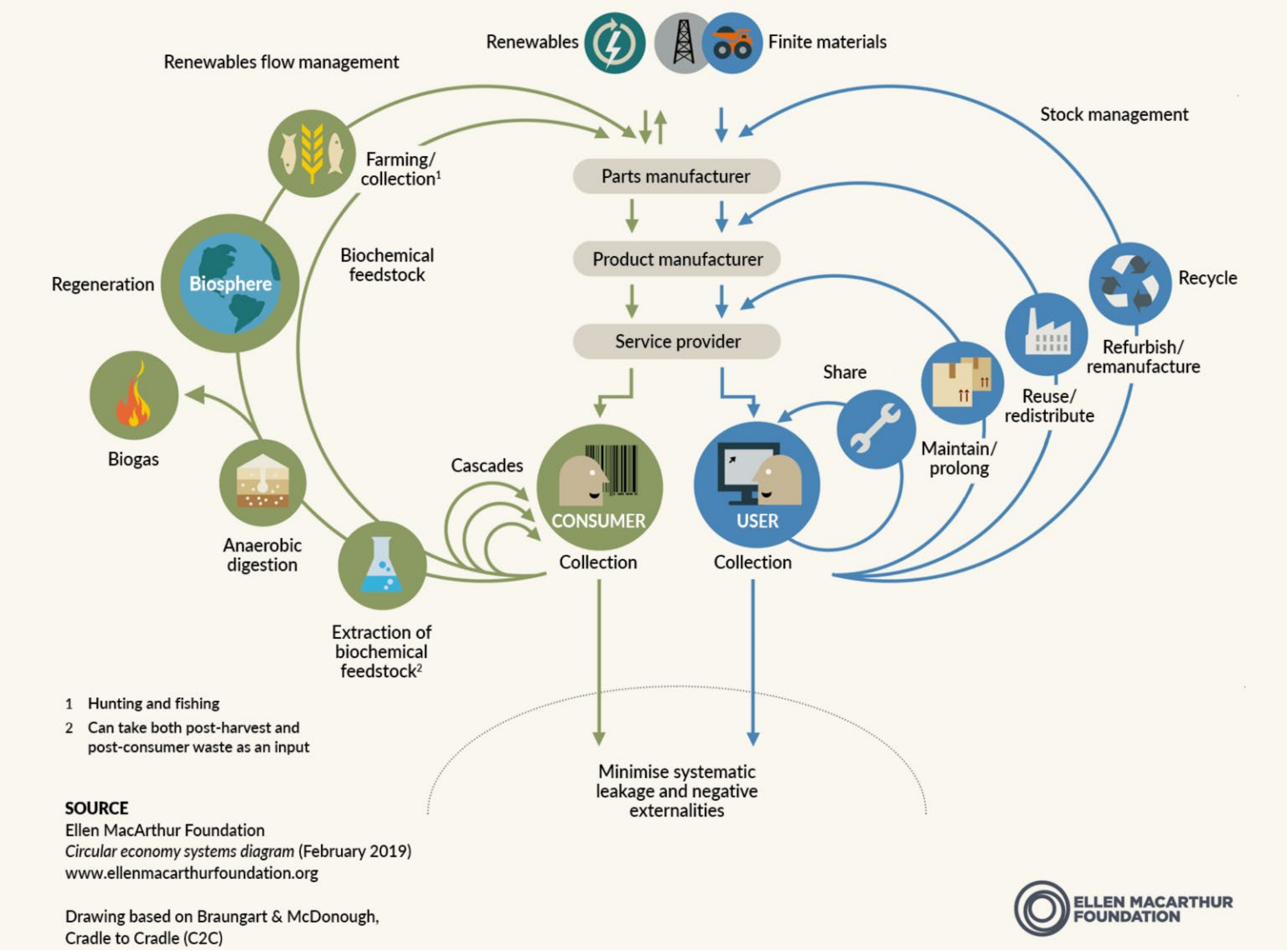


Image source: https://www.eastcham.fi/finnishwastemanagement/circular-economy/

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

System boundaries:

Cradle to Cradle (re-use, recycling; depends on the raw materials or resources used)

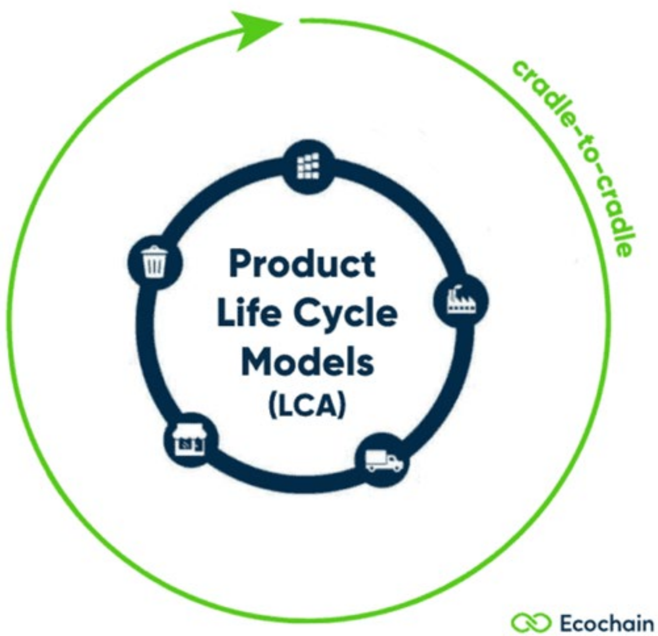


Image source: https://ecochain.com/blog/cradle-to-grave-in-lca/

- It is a variation of Cradle to Grave, adding along the waste stage a recycling, re-using, re-manufacturing etc. process that extends material life cycle as a re-usable resource for another/same product.
- It is also referred to as closed-loop LCA.

Life Cycle Assessment methodologies

System boundaries:

Cradle to Gate

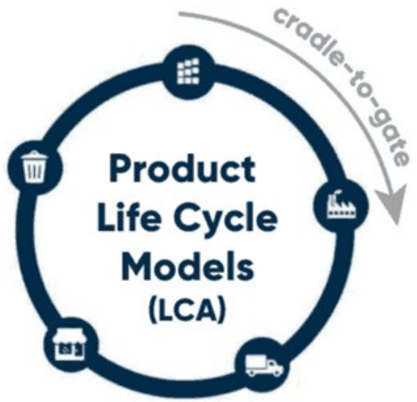


Image source: https://ecochain.com/blog/cradle-to-grave-in-lca/

- It includes all processes (as well as resources in more detailed analysis) from the raw material extraction through the production phase (gate of the factory)
- Cradle-to-Gate only assesses a product (or in wider scope, a service) until it leaves the factory gates, before it is transported to the consumer
- Used to determine the environmental impact of the <u>production</u> of a product

European Institute of Innovation & Technology
Funded by the European Union

Life Cycle Assessment methodologies

Example of System boundaries, includes new proposed:

Research article review on used system boundaries

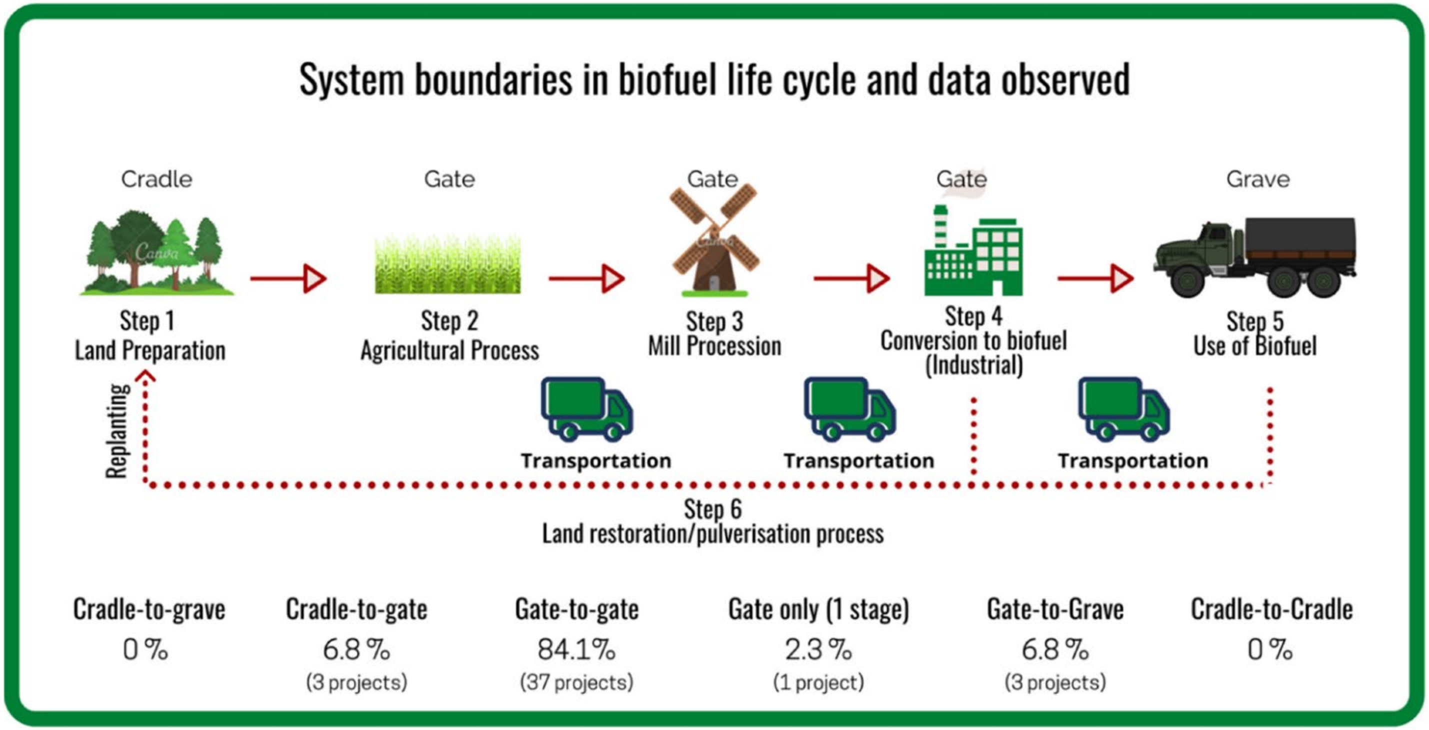


Image source: [Assessment of Indonesia's Future Renewable Energy Plan: A Meta-Analysis of Biofuel Energy Return on Investment (EROI)]

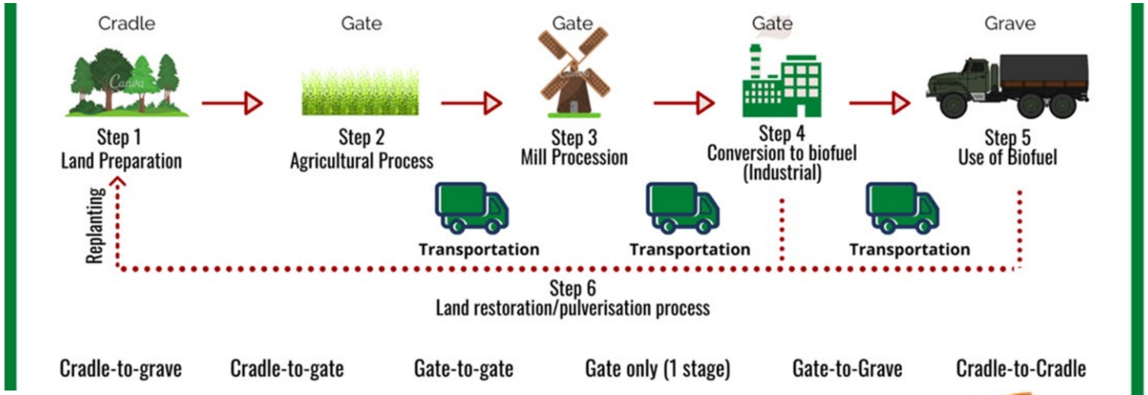
European Institute of Innovation & Technology
Funded by the European Union

Life Cycle Assessment methodologies

System boundaries: Gate to Grave & Gate to Gate

- <u>Gate to Grave</u>: Assessment for the processes from the use and end-of-life phases (everything post-production)
  - Used to determine the environmental impacts of a product once it leaves the factory.

- <u>Gate to Gate</u>: Assessment for the processes from the production phase only
  - Used to determine the environmental impacts of production step or process disregarding the raw materials extraction.



European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

System boundaries for special cases:

- Well-To-Wheel

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

System boundaries for special cases: Well-To-Wheel

- Well-To-Wheel
  - Well-to-wheel is used for the Life Cycle Assessment of transport fuels and vehicles.
  - This approach is more precise in calculating and assigning greenhouse gas emissions and energy usage for various fuels

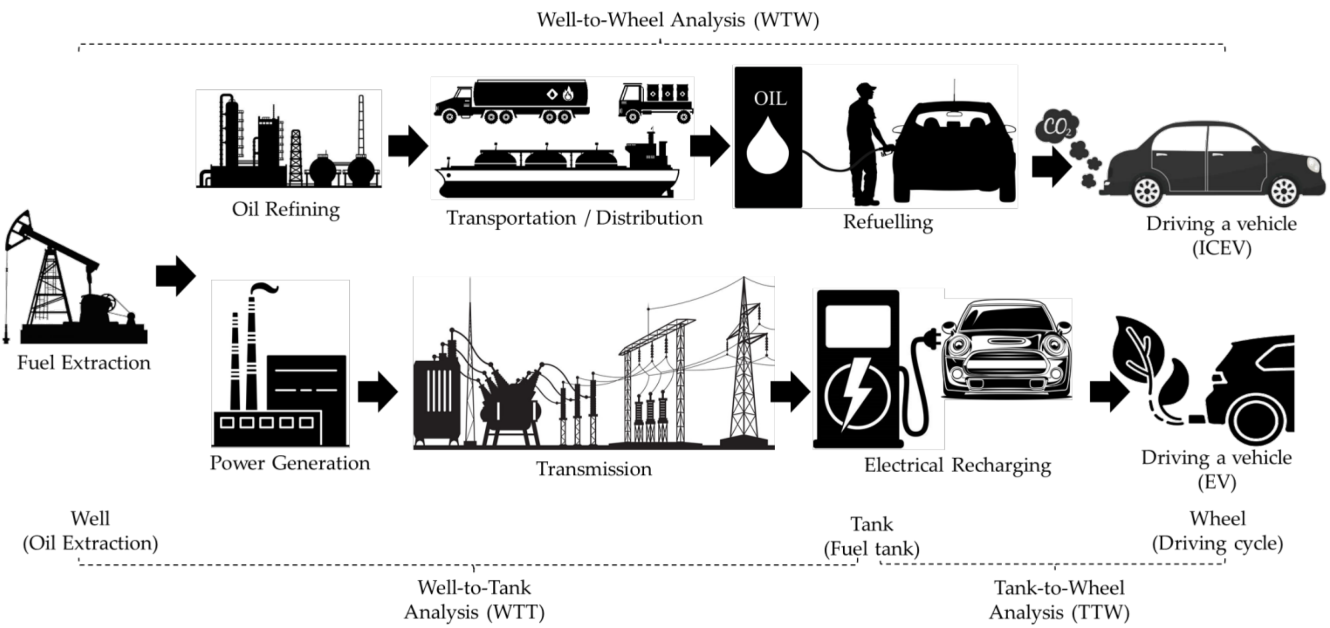


Image source: [The Adoption of Electric Vehicles in Qatar Can Contribute to Net Carbon Emission Reduction but Requires Strong Government Incentives (mdpi.com)]

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

LCA process in general

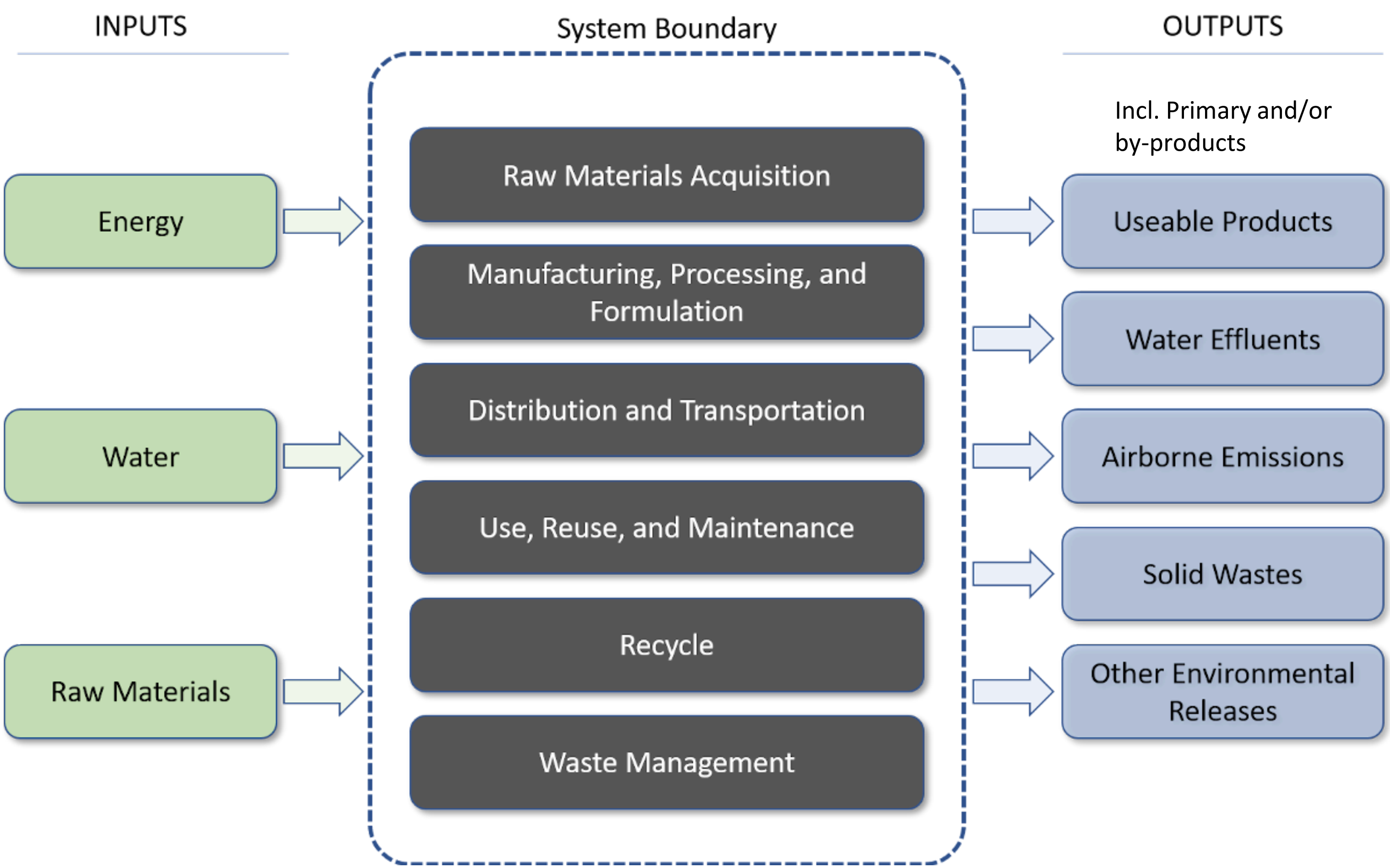
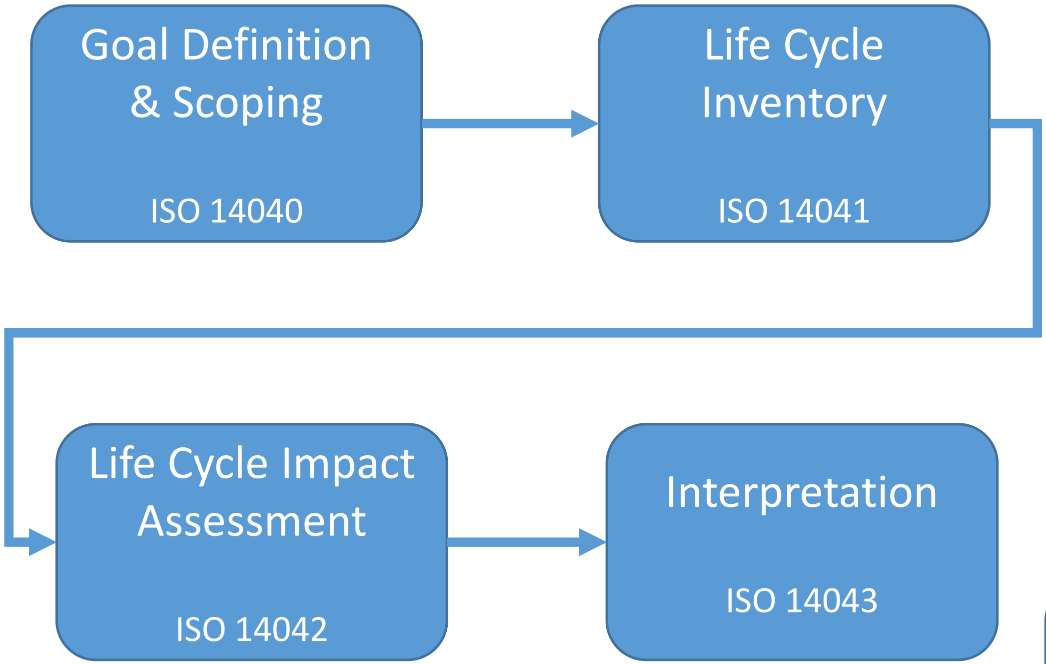


Image source: https://sftool.gov/plan/400/life-cycle-assessment

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3RM

Life Cycle Assessment methodologies

Primary steps in a Life Cycle Analysis



Primary Steps of LCA:

- Defining goal & scope
- LC Inventory analysis
- LC Impact assessment
- Interpretation

ISO 14044

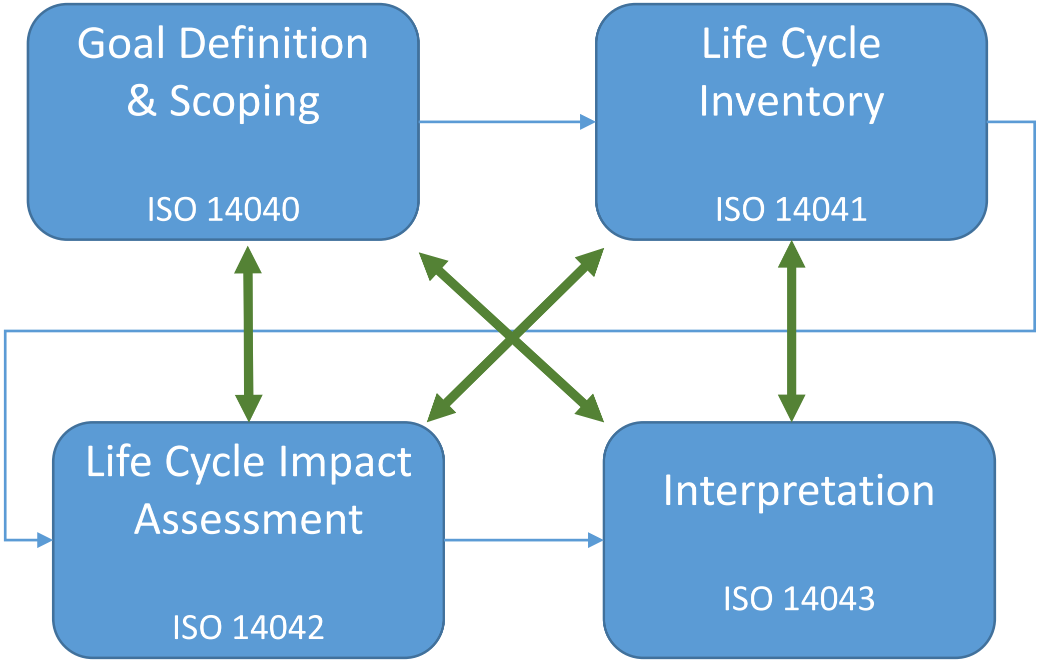
Offers guidelines to LCA

Image source: [Conducting a Life Cycle Assessment - GSA Sustainable Facilities Tool (sftool.gov)]

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3-RM

Life Cycle Assessment methodologies

Primary steps in a Life Cycle Analysis



Primary Steps of LCA:

- Defining goal & scope
- LC Inventory analysis
- LC Impact assessment
- Interpretation

Additional note:
Even though the process or steps seem to be linear there are links between the steps.

Image source: [Conducting a Life Cycle Assessment - GSA Sustainable Facilities Tool (sftool.gov)]

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Defining the Scope of Life Cycle Analysis

- Functional unit, i.e. Description of function that a certain product or service has.
- Reference flow; for instance, solving the relative value of functional unit from other solutions to achieve desired outcome or product.
- Description of the system, i.e. what do you want to do
- System boundaries, as mentioned before
- Allocation procedures
- Impact categories and the impact assessment method
- Data requirements
- Data quality requirements, especially uncertainties & reliability

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Functional unit and Reference flow:

- The Functional unit is the quantified definition or description of the function of a product, e.g. “seating support for one person in a workshop environment” instead of “one workshop chair” or “lighting 10 square meter area with 3000 lux for 50000 hours at 5600K temperature” (modified from source: Guide_Prod_functional_unit2.qxd (mst.dk))

- The Reference flow is the measure or quantity of product components and materials needed to fulfill the function, as defined by the functional unit. E.g. “15 daylight bulbs of 10000 lumen with a lifetime of 10000 hours”

- All data used in the LCA must be calculated or scaled in accordance with this reference flow so that the options or alternatives are comparable.

Life Cycle Assessment methodologies

Example of Function, Functional unit and Reference flow:

Example of function, functional unit and reference flow

Product: beverage container, either a steel can or a glass bottle, each containing 300 ml of beverage

Steel can weight: 10 g
Glass bottle weight: 75 g

You can define function, functional unit and reference flow of this product as:

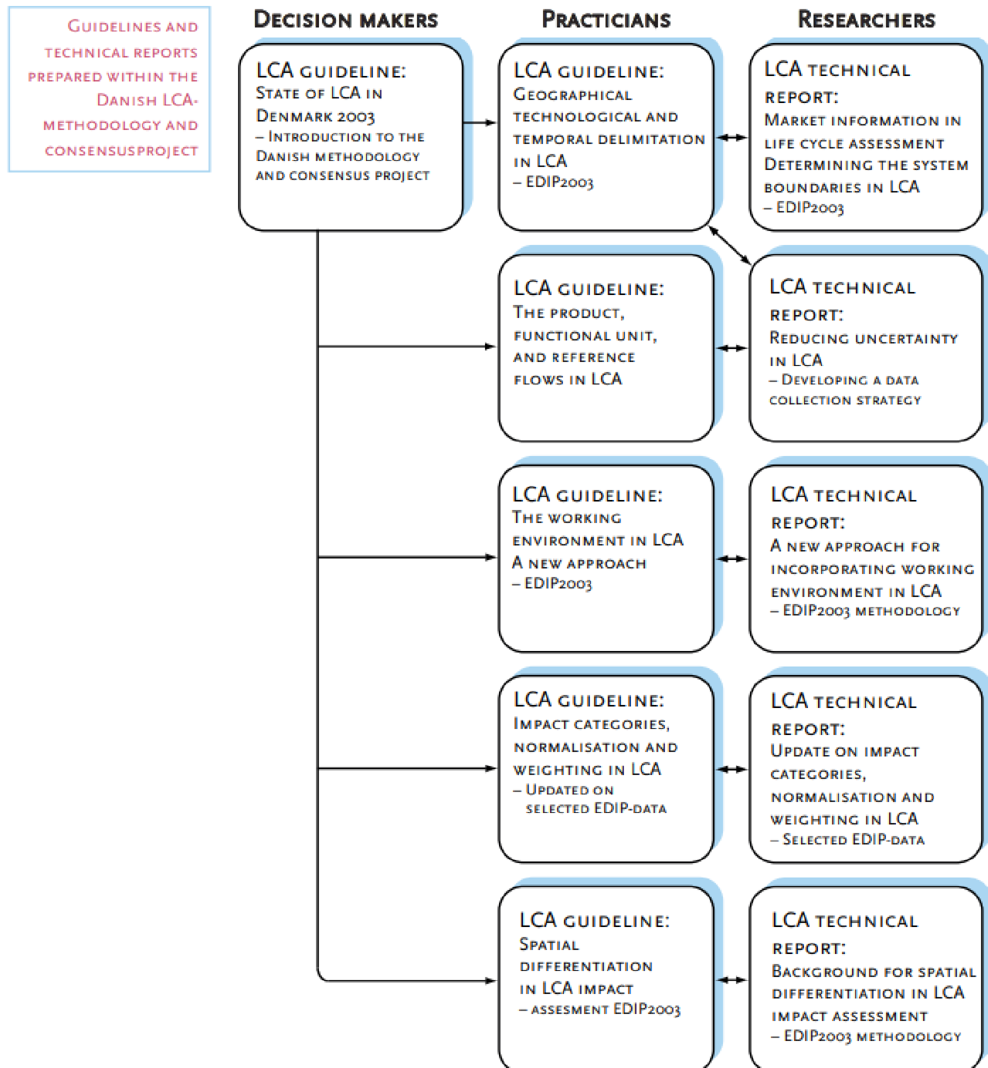
Function: storing beverage for transportation
Functional unit: 300 ml volume
Reference flow: Steel can - 10 g, Glass bottle - 75 g

source: [Life Cycle Assessment Best Practices of ISO 14040 Series (apec.org)]

European Institute of Innovation & Technology
Funded by the European Union

Life Cycle Assessment methodologies

Example of timeline – Developments of Danish LCA for various parties



source: [Guide_Prod_functional_unit2.qxd (mst.dk)]

Life Cycle Assessment methodologies

Data requirements for Life Cycle Assessment:

- Energy, water and raw materials inputs
- Wastes
- Raw material inputs
- Emissions to air, water and soil
- Auxiliary or other inputs
- Other environmental aspects
- (Primary) Products & co-products

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3RM

Life Cycle Assessment methodologies

Data Collection process for Life Cycle Inventory

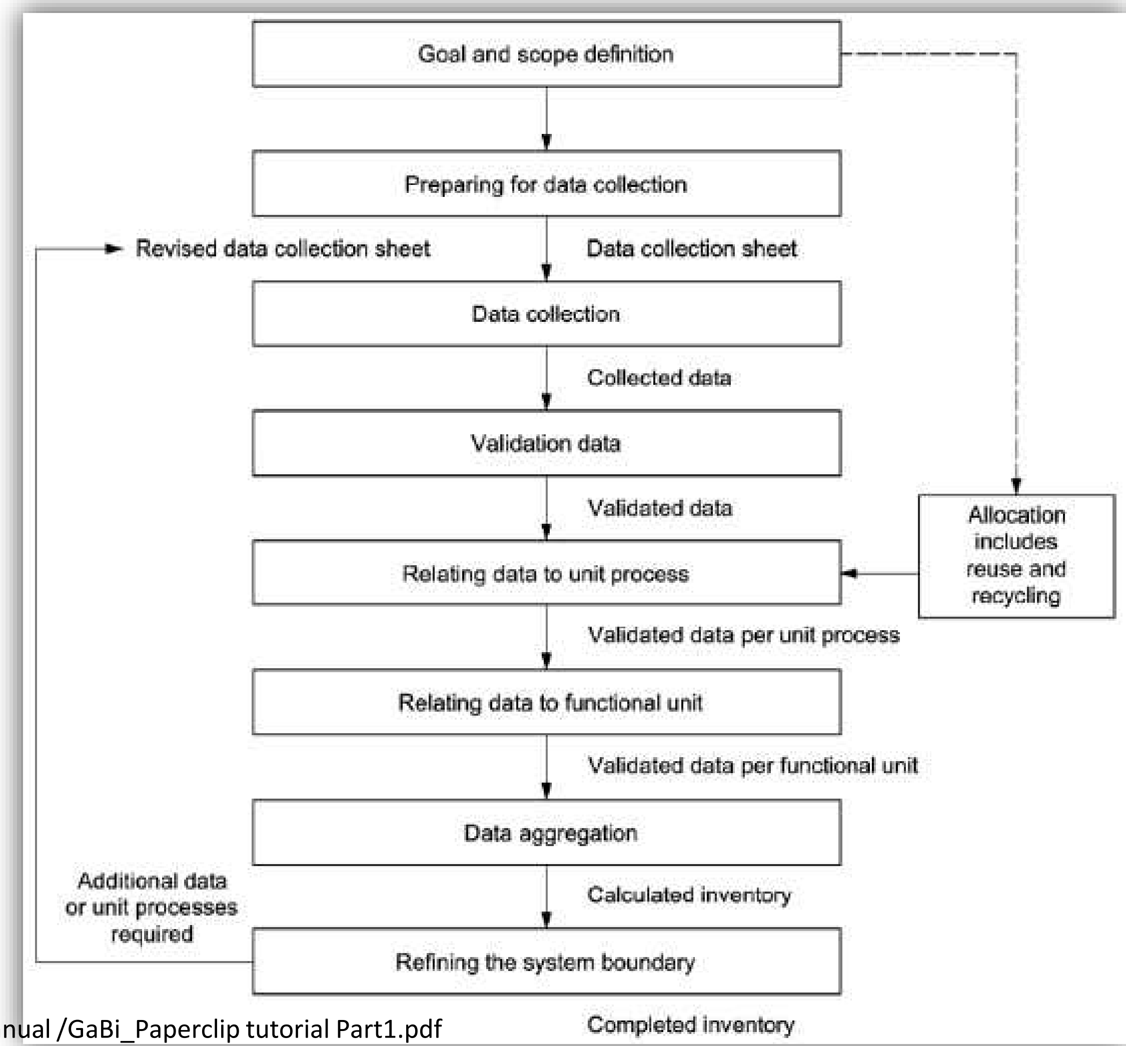


Image source: https://gabisphera.com /fileadmin/GaBi_Manual /GaBi_Paperclip tutorial Part1.pdf

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Factors affecting data quality 1/2:

- Data acquisition: Is the data measured, calculated or estimated? How much of the data required is primary data (in %) and how much data is taken from literature and databases (secondary data)?

- Time-reference: When was this data obtained and have there been any major changes since the data collection that might affect the results?

- Geographical reference: For what country or region is this data relevant? Near the Equator or polar circle?

Life Cycle Assessment methodologies

Factors affecting data quality 2/2:

- Technology: Is the secondary data from literature or databases representative for state-of-the-art-technology or for older technology?
- Precision: Is the data a precise representation of the system?
- Completeness: Are any data missing? How are the data gaps filled?
- Presentative, consistency, reproducibility: Is the data representative, consistent and can it be reproduced?

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Life Cycle Inventory (LCI):

- An industrial system's inputs and outputs are measured and recorded (according to the functional unit).

- By the end of this phase, an inventory list is created that details all input/output data for the system under study.

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Allocation classification:

- Allocation by Mass: The inputs and outputs of a process are assigned to all its products proportionally to their mass

- Allocation by Heating Value: The inputs and outputs of a process are assigned to all its products according to their heating value. This allocation method is often used for production processes of fuels.

- Allocation by Market Value: The inputs and outputs of a process are assigned to all its products according to their market value

Allocation is the partitioning and relating of inputs and outputs of a process to the relevant products and byproducts.

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3 RM

Life Cycle Assessment methodologies

Life Cycle Inventory typical format: Flow Model

- Data collection of the input and output within a list or tabular format would quickly lead to confusion. That is why the Life Cycle Inventory is typically illustrated with a flow model of the product or service manufacturing.

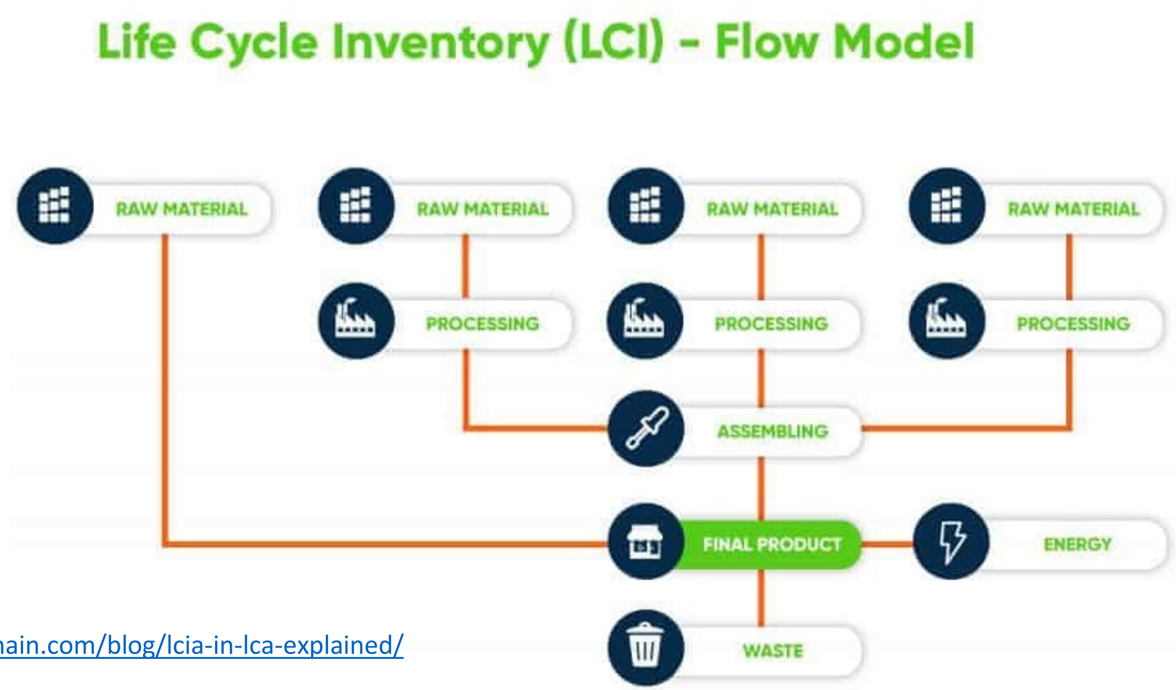


Image source: https://ecochain.com/blog/lcia-in-lca-explained/

European Institute of Innovation & Technology
Funded by the European Union

Life Cycle Assessment methodologies

Life Cycle Inventory, LCI: Example steel manufacturing, scrap steel

Impact category / Energy	**LCIA for 1kg steel scrap**
Primary energy demand, MJ	15.15
Global warming potential (100 years) kg CO_2-e	1.63
Acidification potential, kg SO_2-e	0.0024
Eutrophication potential, kg Phosphate-e	1.83E-04
Photochemical ozone creation potential, kg Ethene -e	0.00075

Table 5: Example impact categories and primary energy demand for 1 kg steel scrap

Image source: [Life cycle inventory (LCI) study (worldsteel.org)]

European Institute of Innovation & Technology

Funded by the European Union

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Life Cycle Inventory, LCI: Example steel manufacturing, Primary energy demand vs production mix

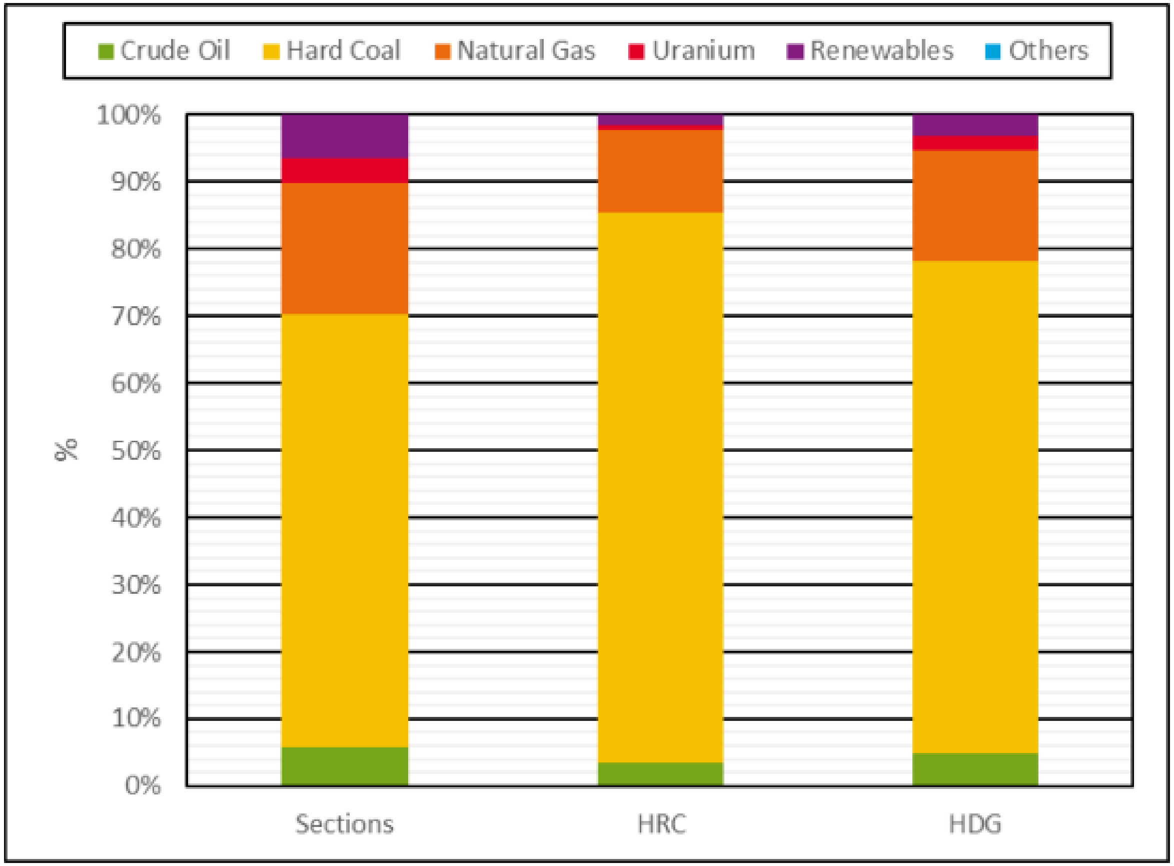


Figure 3: Contributions to primary energy demand of steel products

Image source: Life cycle inventory (LCI) study (worldsteel.org)

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Life Cycle Inventory, LCI: Example steel manufacturing, Recycling credit

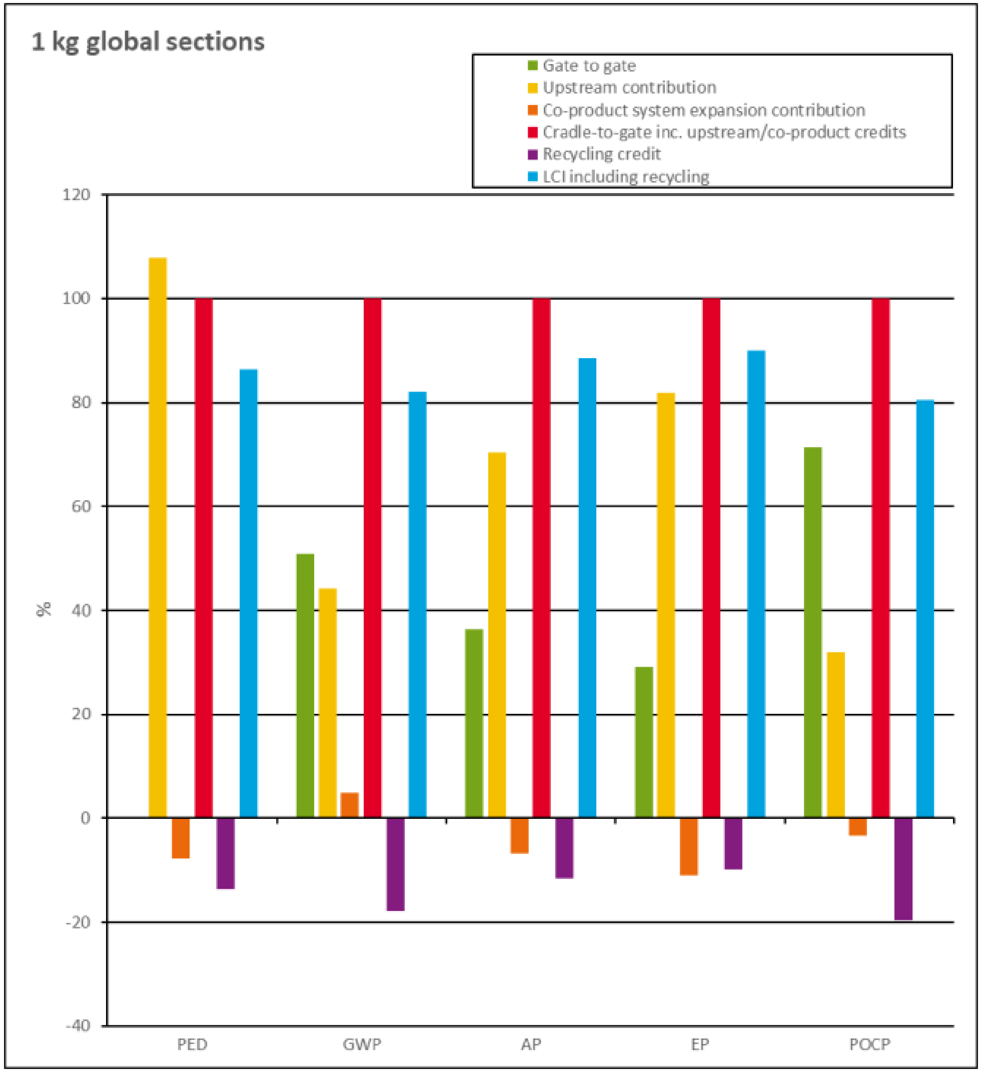


Figure 15: Life cycle contribution to PED and impact categories for steel sections

Image source: Life cycle inventory (LCI) study (worldsteel.org)

European Institute of Innovation & Technology
Funded by the European Union

Life Cycle Assessment methodologies

Life Cycle Inventory, LCI, active directory example:

- Comprehensive, active listing of

[Sectors – ecoinvent]

Few sector- links

[Waste Management & Recycling – ecoinvent]

[Metals – ecoinvent]

[Agriculture, Fishery & Animal Husbandry - ecoinvent]

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

LCA Example

Building lighting options

[LCA Example - GSA Sustainable Facilities Tool (sftool.gov)]

LCA Example

The US Department of Energy has developed an LCA report to help evaluate the energy and environmental benefits of LEDs when compared to incandescent and fluorescent lighting. This analysis follows the four steps outlined on the Conducting LCA page. When using LCA to compare equipment, it is important to establish a common unit of performance by which each will be judged. For lighting, the useful life of the three alternatives below varies greatly. When comparing lighting options, it is important to consider the labor and disposal impacts of bulb replacements.

Figure 1: Number of Lamps Needed to Supply 20 Million Lumen-Hours.[1]

The figure below sums up the results of DOE's study: though the manufacturing of LEDs may have a greater environmental impact than its competition, the dominant source of impact is the lifetime energy use. In 2011, LEDs were roughly equivalent to CFLs with respect to LCA. According to an updated LCA study conducted for the Illuminating Engineering Society in 2018, new A19 LED lamps "all perform better than the 2011 A19 LED on environmental impacts and all are now significantly better than traditional lighting technologies".[3]

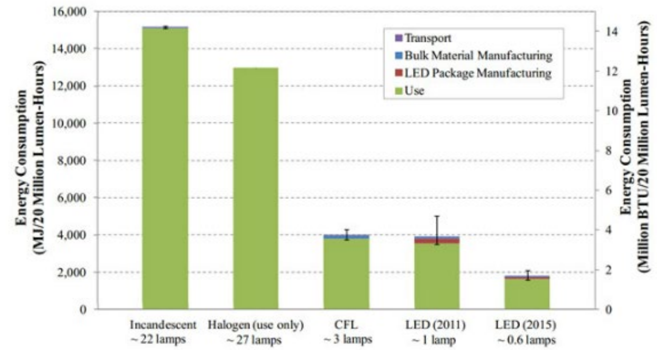


Figure 2: Life-Cycle Energy of Incandescent Lamps, CFLs, and LED Lamps.[2]

[1,2] US Department of Energy, "Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products," Februrary 2012

[3] Illuminating Engineering Society, "Environmental and Energy Improvements of LED Lamps over Time: A Comparative Life Cycle Assessment", October 2018

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3-RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Impact Assessment:

- Evaluating the inventory of data that has been collected in order to make it meaningful in the context of potential damage to the environment or human health.
- Various impacts are assessed in categorized manner (in various impact category).

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Impact Assessment: Impact Categories

- <u>Global warming</u>: Rise in global mean temperature due to Green House Gas (GHG) emissions
- <u>Acidification</u>: Due to excess CO2 emission, PH of ocean decreasing and affecting marine life
- <u>Eutrophication</u>: Excess algae in lake/water body which impacts the ecology
- <u>Smog creation</u>: Impacts human health
- <u>Ozone depletion</u>: Ozone layer in atmosphere depletes and filtration of Ultra Violate rays decreases causing skin diseases

Life Cycle Assessment methodologies

Life Cycle Impact Assessment (LCIA): Steps of LCIA

- The U.S. Environmental Protection Agency (EPA) breaks down an LCIA into the following steps:

- Selection and definition of impact categories
- Classification
- Characterization
- Normalization
- Grouping
- Weighting
- Evaluating and reporting LCIA results

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Impact Assessment: Impact Categories, example WorldSteel case from earlier

- Please note: The impact assessment categories are choices, not "set in stone"

The following LCIA categories, which have been chosen as examples, are:

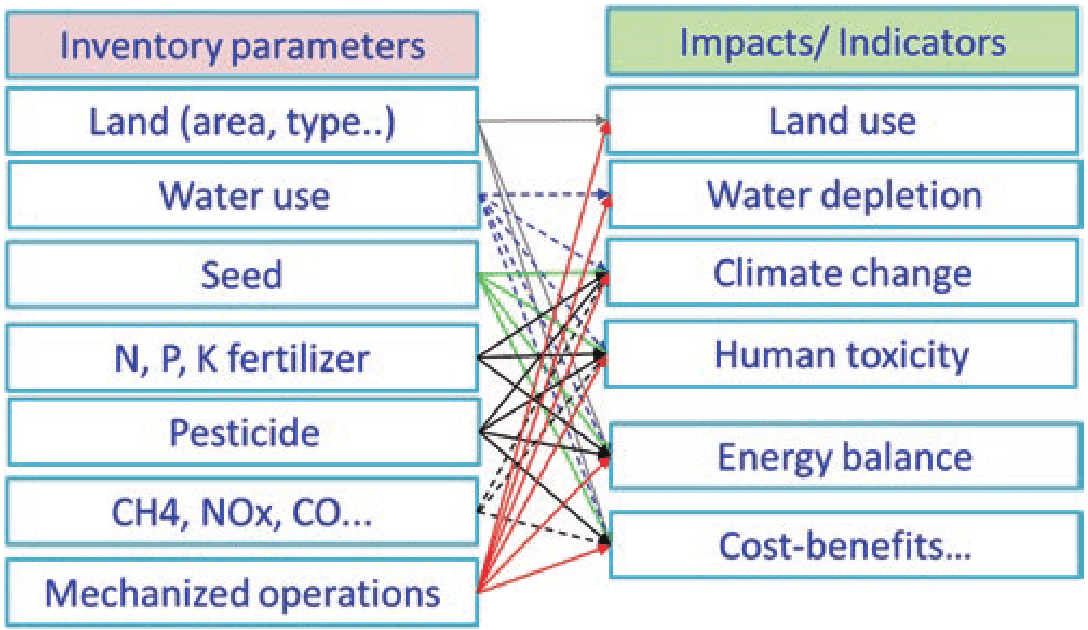
- Global Warming potential (GWP 100 years): an impact assessment level with global effect; for steel products, the GWP is mainly caused by CO_2 and methane emissions which account for over 95% of GHG emissions from the steel industry.
- Acidification potential (AP): an impact assessment level with local effect; within the steel industry, AP is mainly caused by SO_2 and NO_x emissions.
- Eutrophication potential (EP): an impact assessment level with local effect; within the steel industry, EP is mainly caused by NO_x emissions.
- Photochemical ozone creation potential (POCP): an impact assessment level with local effect; within the steel industry, POCP, also known as summer smog, is mainly caused by carbon monoxide emissions.

source: [Life cycle inventory (LCI) study (worldsteel.org)]

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

Life Cycle Impact Assessment (LCIA): Example, agriculture



Different output of production process are linked with environmental impacts, single or multiple at the same time.

All outputs are converted into few categories and impacts are assessed.

Image source: https://www.researchgate.net/publication/337606167_Life_Cycle_Assessment_Applied_in_Rice_Production_and_Residue_Management

Life Cycle Assessment methodologies

Life Cycle Impact Assessment (LCIA): Example

- All outputs are converted into few categories and impacts are assessed.
- Exhaustive list (one available at least) of impact categories can be found at [Ecochain website]

Table 1. Environmental impacts

Impact category / Indicator	Unit	Description
Climate change – total, fossil, biogenic and land use	kg CO_2-eq	Indicator of potential global warming due to emissions of greenhouse gases to the air. Divided into 3 subcategories based on the emission source: (1) fossil resources, (2) bio-based resources and (3) land use change.
Ozone depletion	kg CFC-11-eq	Indicator of emissions to air that causes the destruction of the stratospheric ozone layer
Acidification	kg mol H+	Indicator of the potential acidification of soils and water due to the release of gases such as nitrogen oxides and sulphur oxides
Eutrophication – freshwater	kg PO_4-eq	indicator of the enrichment of the freshwater ecosystem with nutritional elements, due to the emission of nitrogen or phosphor-containing compounds
Eutrophication – marine	Kg N-eq	Indicator of the enrichment of the marine ecosystem with nutritional elements, due to the emission of nitrogen-containing compounds

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3-RM

Life Cycle Assessment methodologies

Life Cycle Assessment: Interpretation

Identify significant issues based on the LCI and LCIA phase

Evaluate the study itself, how complete it is, whether it is done sensitively and consistently & account for uncertainty

Provide conclusions, limitations, and recommendations

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

Conclusions or takeaways

- Life cycle assessment is method to assess the impact of a product or service on environment.
- LCA can fulfill many objectives from policy making, legislation, alternative selection to marketing – to name only few.
- LCA is a multi-step process including goal & scope, inventory, assessment & interpretation. It also includes possibility of revision or updating the scoping.
- LCA is ever-developing tool and LCI is growing alongside knowledge gathered and from executed LCA's from various processes, products and services.

European Institute of Innovation & Technology
Funded by the European Union
HEI4S3 RM

Life Cycle Assessment methodologies

LAPIN AMK
Lapland University of Applied Sciences

List of sources in order of appearance

Life Cycle Initiative	https://www.lifecycleinitiative.org/activities/life-cycle-terminology-2/
British Plastíc Federation	Life Cycle Analysis (LCA) - A Complete Guide to LCAs (bpf.co.uk)
World Auto Steel	www.ahssinsights.org
Reuters	https://www.reuters.com/article/us-france-paris-autos-idUSKBN1CH0SI
SFTool	https://sftool.gov/plan/402/environmental-product-declarations-epds
EPD International	Data (environdec.com)
GaBi software	GaBi Modelling Principles (lca-data.com)
Bank Of Luxembourg	The Circular Economy - More than just recycling - BIL Investment Insights
EcoChain	https://ecochain.com/blog/cradle-to-grave-in-lca/
EastCham Finland	Circular Economy - EastCham Finland ry
PBL Netherlands Environmental Assessment Agency	https://www.pbl.nl/en/publications/circular-economy-measuring-innovation-in-product-chains
APEC	Life Cycle Assessment Best Practices of ISO 14040 Series (apec.org)
Prananta et al.	Assessment of Indonesia's Future Renewable Energy Plan: A Meta-Analysis of Biofuel Energy Return on Investment (EROI)
Al-Buenain A- et al., 2021	The Adoption of Electric Vehicles in Qatar Can Contribute to Net Carbon Emission Reduction but Requires Strong Government Incentives (mdpi.com)
Danish Ministry of the Environment	Guide_Prod_functional_unit2.qxd (mst.dk)
GaBi	https://gabisphera.com /fileadmin/GaBi_Manual /GaBi_Paperclip tutorial Part1.pdf
EcoChain	https://ecochain.com/blog/lcia-in-lca-explained/
WorldSteel Association	Life cycle inventory (LCI) study (worldsteel.org)
Nguyen, V. H. et al.	(PDF) Life Cycle Assessment Applied in Rice Production and Residue Management (researchgate.net)

I'm fire. I'm ice.
I'm a storm. I'm calm.
I'm strong and sensitive.

I have the Northern Factor

LAPIN AMK
Lapland University of Applied Sciences

European Institute of Innovation & Technology

Funded by the European Union

HEI4S3 RM

European Institute of
Innovation & Technology

EIT HEI Initiative

Innovation Capacity Building
for Higher Education

Funded by the
European Union