IKK
Institut für Kunststoff- und Kreislauftechnik
Prof. Dr.-Ing. Hans-Josef Endres

Evangelische Akademie Loccum in Kooperation mit NEWIN: Regionale Wirtschaftsförderung zwischen globaler Transformation und neuen Förderpolitiken

Life Cycle Assessment zur Bewertung der Nachhaltigkeit – Herausforderungen und strategische Handlungsoptionen für die Industrie

Prof. Dr.-Ing. Hans-Josef Endres
IKK – Institut für Kunststoff- und Kreislauftechnik
Leibniz Universität Hannover

Loccum, 12. September 2022

Leibniz Universität Hannover
Produktionstechnisches Zentrum Hannover

Gottfried Wilhelm Leibniz University Hannover (LUH)

IKK
Institut für Kunststoff- und Kreislauftechnik

Facts & Statistics
Founded
- 1831
- T9 German University

Overall Budget (2019)
- 266.7 MEUR

Students (2019/20 WiSe)
- *30.196*

Degree Courses
- 84 Degree Programs
- 9 Faculties

Staff
- 5.138 Staff
  - 3.320 Research and Teaching Staff incl. 348 Professors
  - 1.744 Technical and Administrative Staff
  - 74 Apprentices

Buildings
- 325.720m² Floor Space
- 167 Buildings

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Main Building of the Leibniz University of Hannover

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Produktionstechnisches Zentrum Hannover

Faculty of Mechanical Engineering
Facts & statistics

IKK Institut für Kunststoff- und Kreislauftechnik

20 Institutes
900 Employees
Research funding: 75 Mio Euro p.a.
75 Doctoral Theses p.a.
5.000 Students

Hannover Center for Production Technology (PZH) opened in 2014

Faculty of Mechanical Engineering

Mechanical Engineering Campus of Leibniz University Hannover (2020)

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IKK - Institute of Plastics and Circular Economy
Research Focus

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Color batch for thermoplastics

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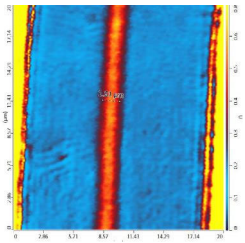

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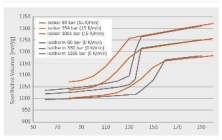

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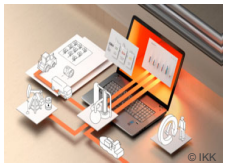
Plastics Technology and Recycling
Plastics Analytics
IKK
Sustainability Assessment
Material Testing



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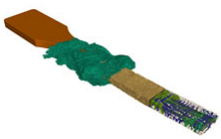

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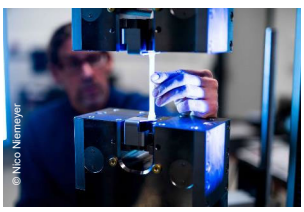

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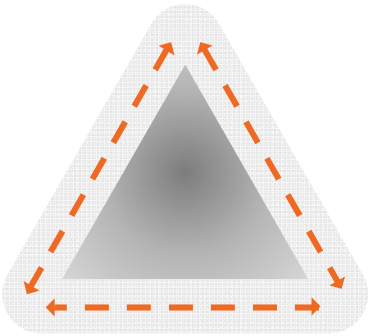
Produktionstechnisches Zentrum Hannover

Preis, Performance und Nachhaltigkeit

IKK Institut für Kunststoff- und Kreislauftechnik

Nachhaltigkeit



Preis ⟷ Performance

Preis Performance

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Introduction to sustainability

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Source: www.unsplash.com

Definition of sustainability

Year	Author/Event	Definition/Declaration
1713	**Hans-Carl von Carlowitz** "Sylvicultura Oeconomica - Anleitung zur wilden Baumzucht"	Forests to be conserved. People, should save wood, conserve forests by sowing and planting trees, and seek "surrogata" or alternatives to wood. **All in all, people should only harvest as much wood as could regrow**.
1972	First UN and UNEP world Conference on the Human Environment, Stockholm, **Club of Rome**	Under the slogan „**Only One Earth**", a declaration and action plan for environmental conservation was published.
1987	**Brundtland Report**	„Sustainable development is development that meets the **needs of present without compromising the ability of future generations** to meet their own needs".
1992	**UN Conference** on Environment and Development (Earth Summit, Rio)	In the **Rio Declaration and Agenda 21 Action Plan**, principles of sustainable development and the framework for future tasks were established
2000	United Nations	Declaration containing eight Millennium Development Goals (MDGs) set by 2015.
2015	**UN** Sustainable Development Summit, New York	The UN 2030 Agenda for Sustainable Development was published, setting up **17 Sustainable Development Goals** which should be achieved by 2030.

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Definition of sustainability

Sustainable Development Goals

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Definition of sustainability

IKK Institut für Kunststoff- und Kreislauftechnik

Goal 12 - Sustainable consumption and production - Germany (2021)

SDG 12. Ensure sustainable consumption and production patterns				
12.1.a	**Sustainable consumption** *Making consumption environmentally and socially compatible*	Market share of products certified by publicly managed eco-labelling schemes (in future: market share of products and services bearing trustworthy and demanding eco- and social labels)	Increase the market share to 34 % by 2030	
12.1.ba		Global environmental impact by private household consumption – use of raw materials	Steady reduction	
12.1.bb		Global environmental impact by private household consumption – energy consumption	Steady reduction	
12.1.bc		Global environmental impact by private household consumption – CO_2 emissions	Steady reduction	
12.2	**Sustainable production** *Steadily increasing the proportion of sustainable production*	EMAS eco-management	5,000 locations of organisations by 2030	
12.3.a	**Sustainable procurement** *Giving shape to the public sector's exemplary role in sustainable procurement*	Paper bearing the Blue Angel label as a proportion of the total paper consumption of the direct federal administration	Increase the proportion to 95 % by 2020	–
12.3.b		CO_2 emissions of commercially available vehicles in the public sector	Significantly reduce	–

Status of the indicators

- Goal is (almost) reached
- Development is heading in the right direction, but between 5 % and 20 % of the goal will not be met
- Development is heading in the right direction, but a gap of more than 20 % will remain
- Development is heading in the wrong direction

Source: The Federal Government of Germany, 2021

Sustainability assessment

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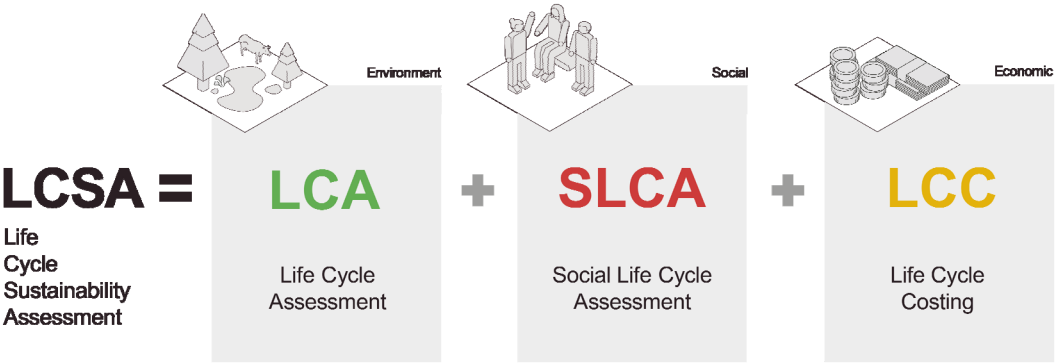
Source: www.unsplash.com

Definition of LCSA



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Life cycle assessment (LCA)

Source: www.unsplash.com

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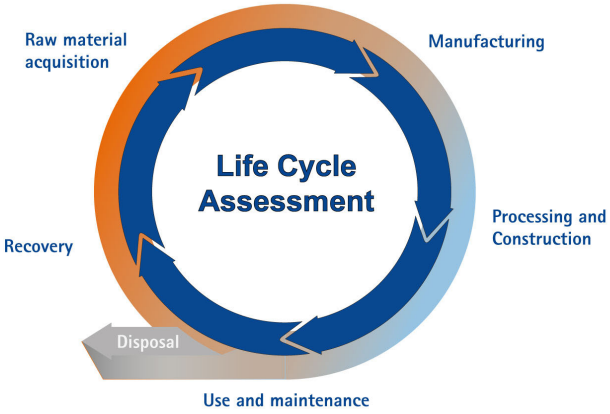
Definition of LCA

„LCA studies the environmental aspects and potential impacts throughout a product`s life (i.e. cradle to grave) from raw material acquisition through production, use and disposal“



Source: Adapted from LBP – Universität Stuttgart 2015

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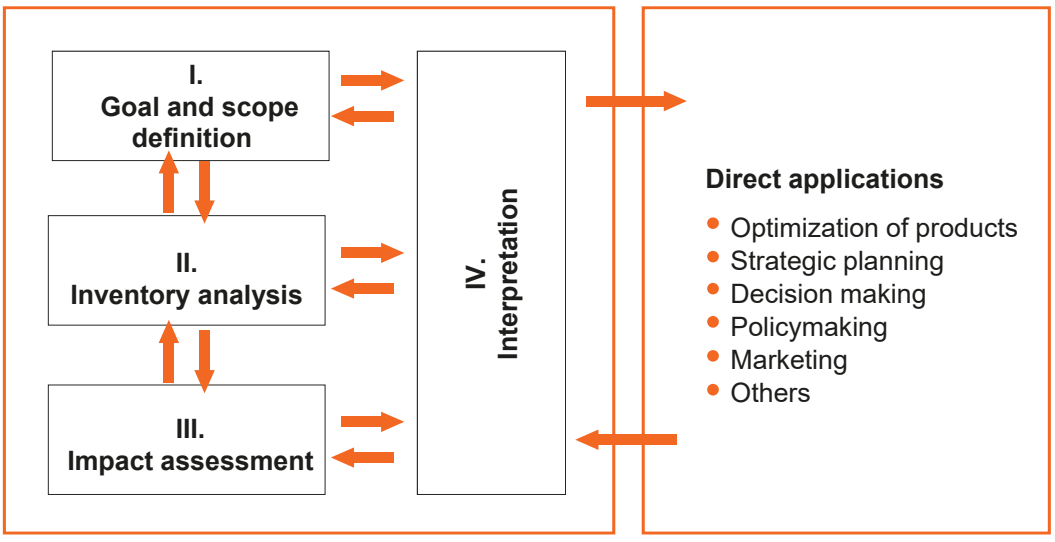
Steps of an LCA



Source: Adapted from ISO 14040

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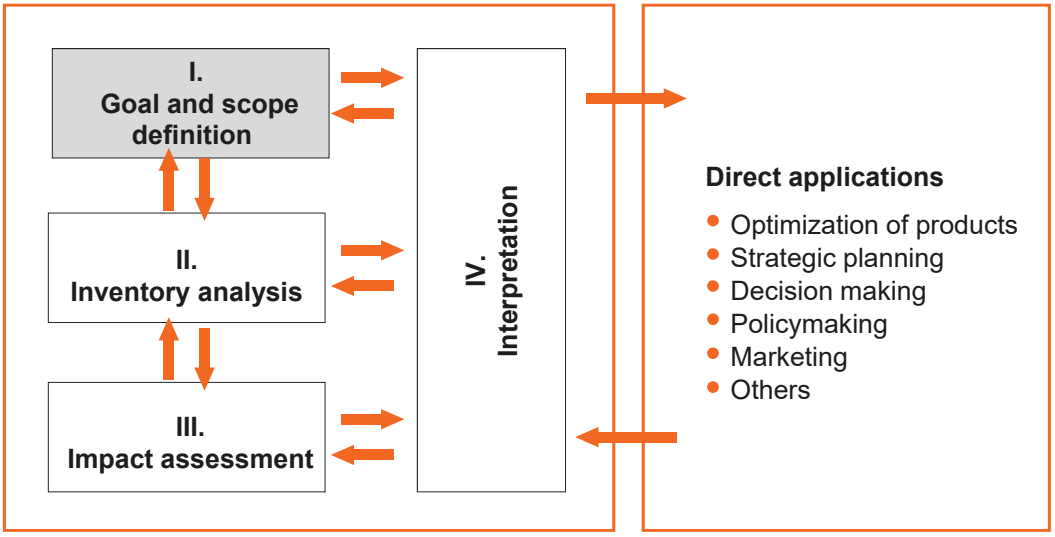
Steps of an LCA



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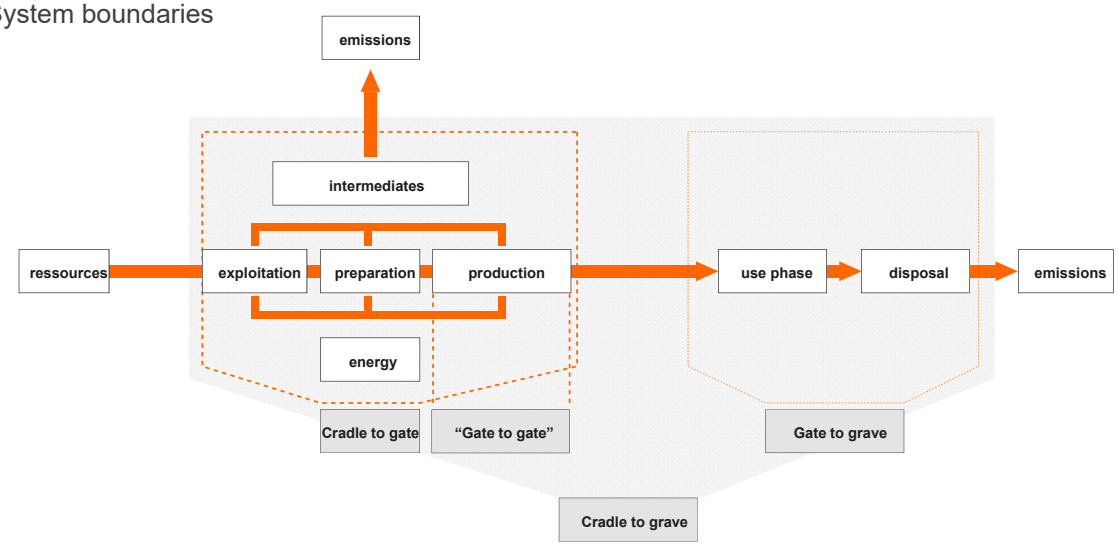
I. Step of LCA – Goal and Scope

System boundaries



Source: Adapted from GaBi Handbook

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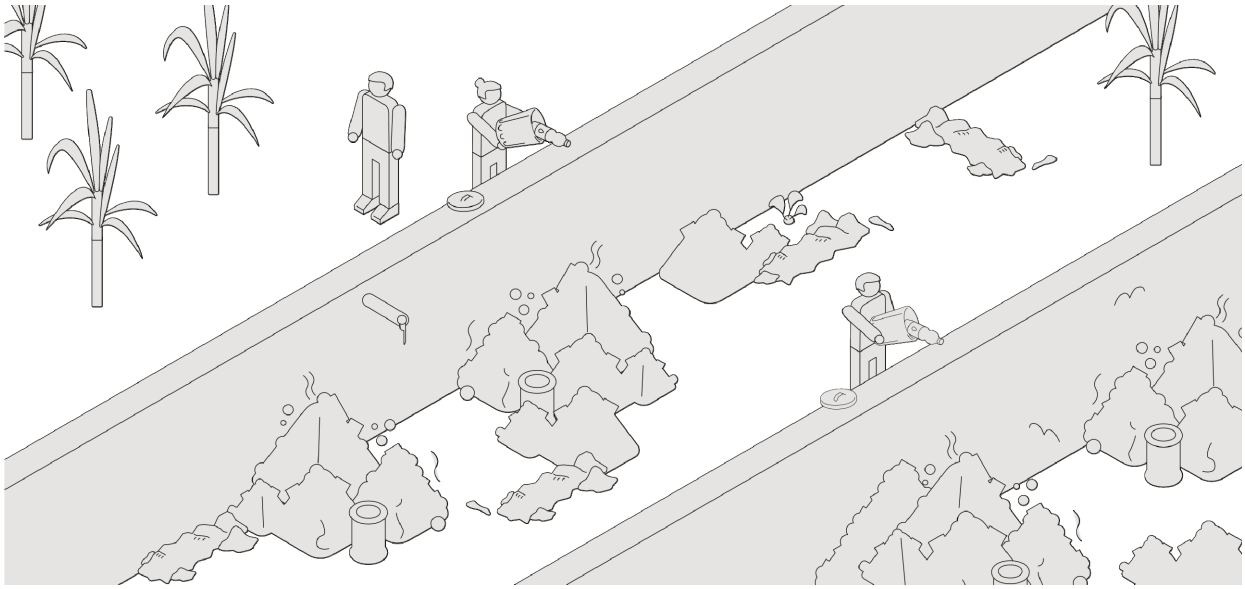
Burden shifting – one solution creates a new problem



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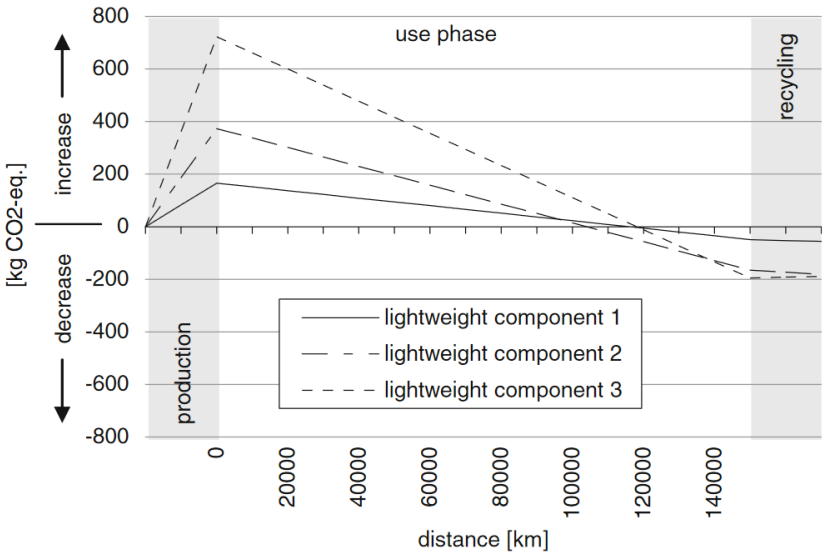
Burden shifting – solving a problem by creating a new problem



Source: Koffler et al. 2010

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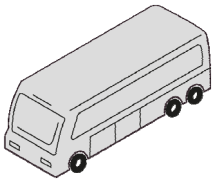
Object of the assessment

Object of the assessment (functional unit):

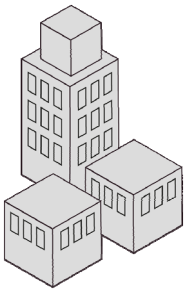
Definition: Quantified performance of a product system for use as a reference unit

Generate Light

Transport People



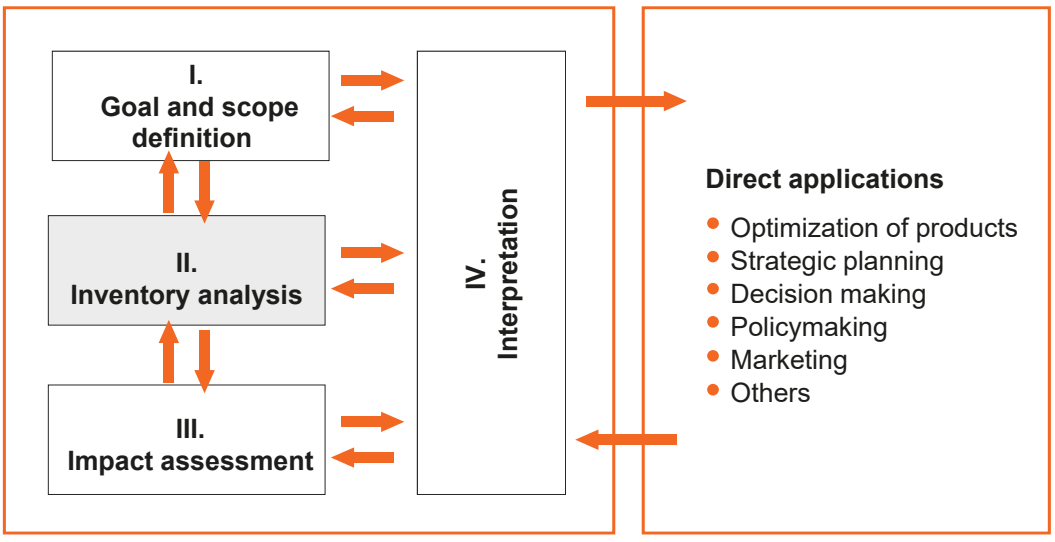
House Students



Examples of functional units:
- Light bulb functional unit might be 1,000,000 lumen-hours of light
- Bus functional unit might be 10,000 passenger-kilometer
- Dormitory building functional unit might be house 200 students for one year

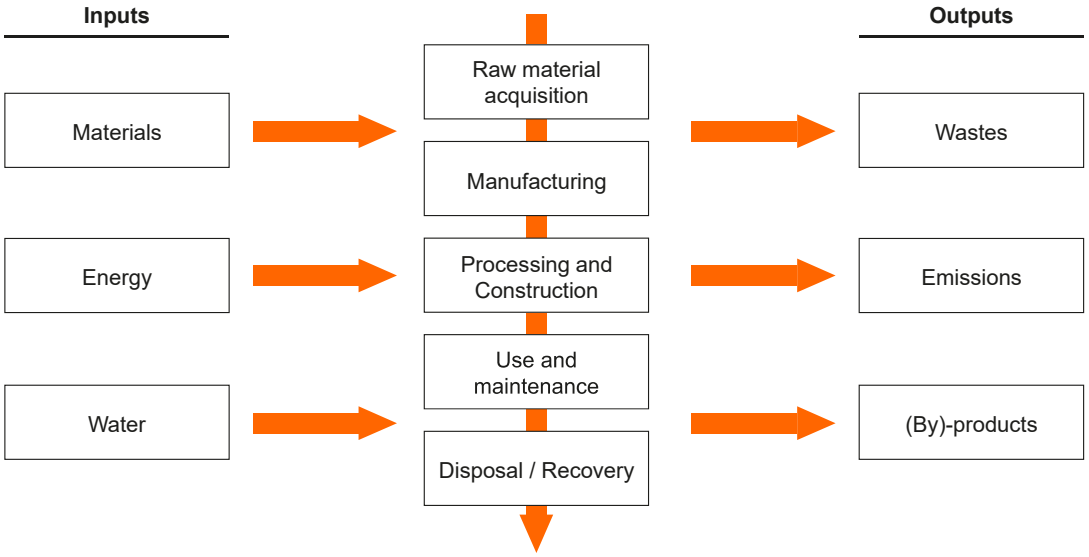
Source: Adapted from ISO 14044 and Haselbach and Langfitt 2015

Steps of an LCA



Source: Adapted from ISO 14040

II. Step of LCA - Inventory analysis



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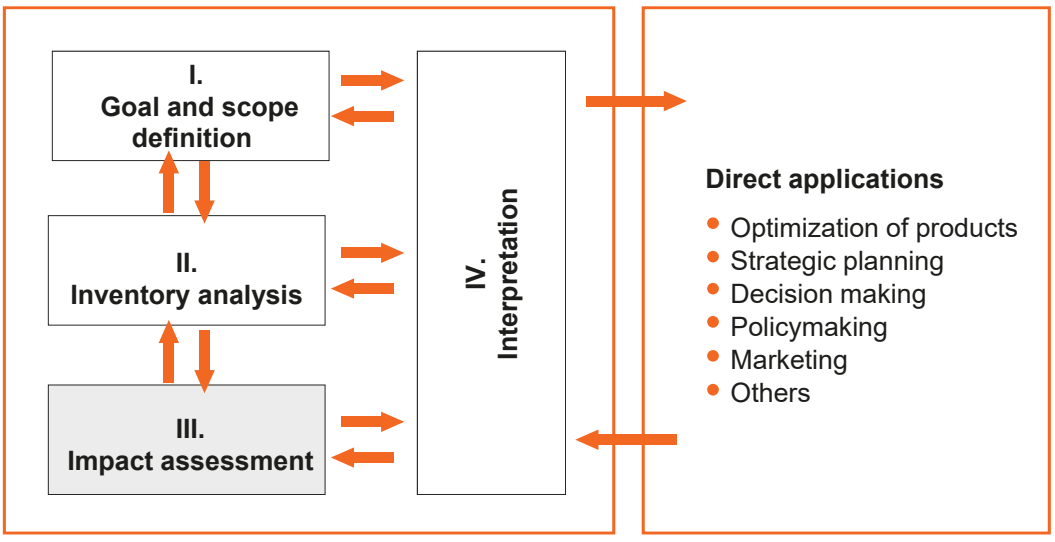
Steps of an LCA



Source: Adapted from ISO 14040

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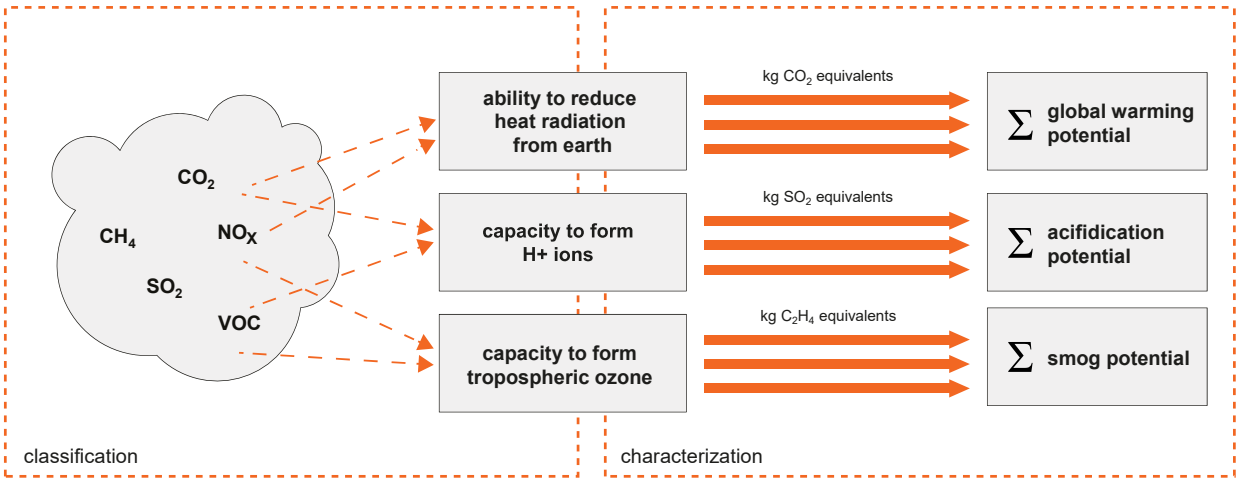
III. Step of an LCA - Impact assessment



Source: Adapted from EU2019

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Impact categories

Impact category	Impact category Indicator	Unit	Characterization model	Robustness
Climate change, total [1]	Radiative forcing as global warming potential (GWP100)	kg CO2 eq	Baseline model of 100 years of the IPCC (based on IPCC 2013)	I
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq	Steady-state ODPs as in (WMO 2014 + integrations)	I
Human toxicity, cancer [2]	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model 2.1 (Fankte et al., 2017)	III
Human toxicity, non-cancer [2]	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model 2.1 (Fankte et al., 2017)	III
Particulate matter	Impact on human health	disease incidence	PM method recommended by UNEP (UNEP 2016)	I
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq U^{235} eq	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al., 2000)	II
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe 2008	II
Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al., 2008)	II

[1] The indicator "Climate Change, total" is constituted of three sub-indicators:
Climate Change, fossil; Climate Change, biogenic; Climate Change, land use and land use change.

Source: EU 2019

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Impact categories

Impact category	Impact category Indicator	Unit	Characterization model	Robustness
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al.	II
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe	II
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe	II
Ecotoxicity, freshwater [2)]	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	USEtox model 2.1 (Fankte et al., 2017)	III
Land use	Soil quality index [3)] Biotic production Erosion resistance Mechanical filtration Groundwater replenishment	Dimensionless (pt) kg biotic production kg soil m3 water m3 groundwater	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	III
Water use	User deprivation potential (deprivation-weighted water consumption)	m3 world eq	Available WAter REmaining (AWARE) as recommended by UNEP, 2016	III
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)26	MJ	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002	III

[2)] Toxicity indicators also have three subindicators ,but only the sum of the three shall be reported (characterisation model modified by JRC)
[3)] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for land use.

Source: EU 2019

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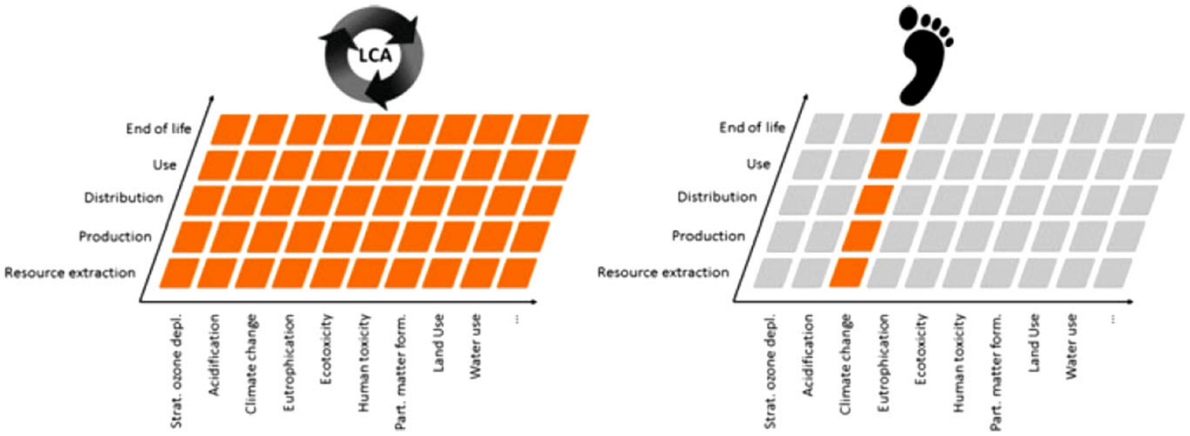
GWP or CO_2-Footprint or LCA?



Source: Hauschild et al. 2018

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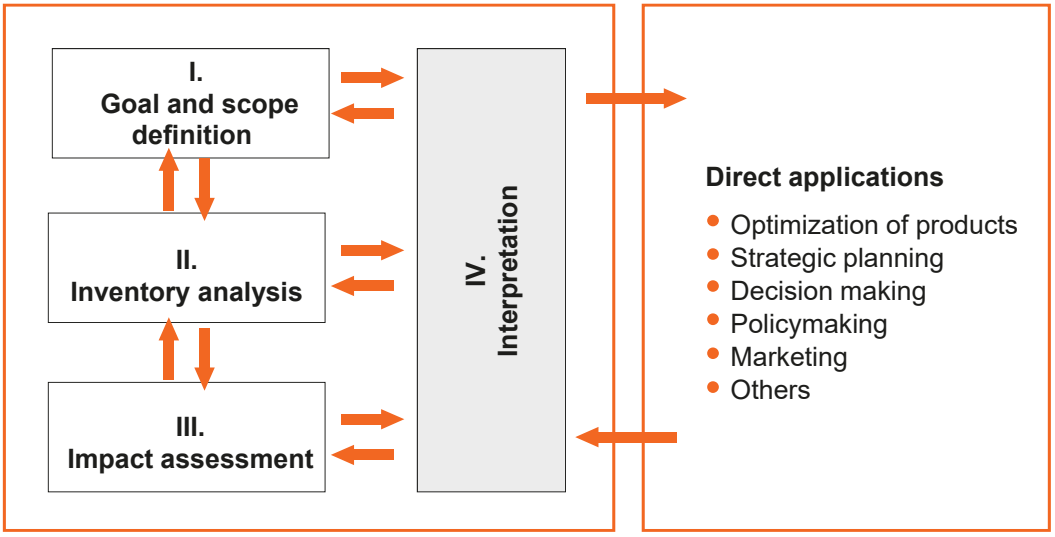
Steps of an LCA



Source: Adapted from ISO 14040

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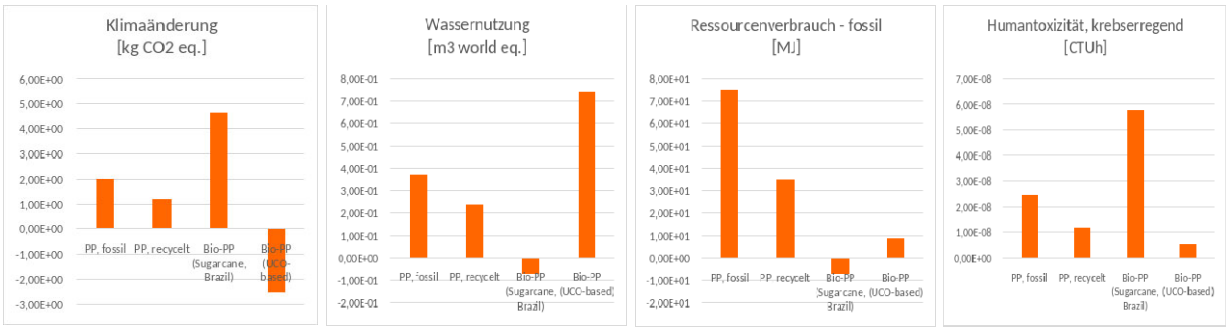
Ecological Impacts of PP, Bio-PP and r-PP (mechanically recycled) based on 1kg – Cradle to Gate



Summary

- **Recycling plastics is about 50% better than producing virgin materials in all various categories**
- **Biobased plastics are sometimes better, sometimes worse than petro-based counteroarts in the various categories. It depends strongly on the process and the LCA parameters**

Source: Compilation of Nessie et. al. (2020) and Moretti et al. (2020)

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Zusammenfassung

IKK Institut für Kunststoff- und Kreislauftechnik

- **Ökobilanzierung bietet einige Freiheitsgrade (Systemgrenzen, betrachtetes Produkt, Cut off, Transportsysteme, Energietyp, …)**
- **LCA ist das beste Instrument, das wir derzeit zur ökologischen Nachhaltigkeitsbewertung und zur ökostrategischen Weiterentwicklung haben**
- **Handlungsempfehlung:**
  - **Zielsetzung für LCA formulieren (Produkt bzw. funktionelle Einheit, Systemgrenzen, Adressat, …)**
  - **Erhebung der Primärdaten nur mit Ihrer Mitwirkung**
  - **Nicht nur CO2, sondern möglichst vollständige Bilanzierung (16 Wirkungskategorien)**
  - **Hot Spot Analyse zur Verbesserung der eigenen Produkte/Prozesse nutzen**
  - **Frühzeitige Einbindung der Reviewer in den LCA-Prozess**
  - **LCA-Kompetenz im eigenen Haus aufbauen**

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- Für weitere Infos siehe auch: https://www.youtube.com/watch?v=7B19cuEbE34 -

Das Plastikdilemma: Kunststoffe und Nachhaltigkeit – ein Widerspruch?

Veranstaltungsreihe „Herrenhausen Late“ der VolkswagenStiftung

Prof. Dr.-Ing. Hans-Josef Endres

30. November 2021

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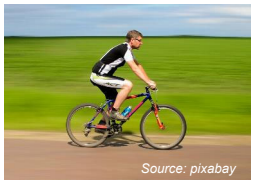
Plastic products - what are the alternatives?



Coffee is also not sustainable, but enjoyable