Towards the big picture - from one-dimensional footprints to complete environmental sustainability assessments

Ralph K. Rosenbaum
Content

• A short history of LCA

• Future trends in LCA
  • Impact assessment
  • Uncertainty assessment and probabilistic LCA
  • New tendencies and expansions of classic LCA
  • Policy and global harmonisation

• Footprint or LCA?
Master equation for environmental impacts

Environmental Impact = Population \cdot \frac{GDP}{Person} \cdot \frac{Impact}{GDP}

- Wealth/growth
- Consumption/material affluence
- Economic activity
- Technological efficiency e.g. via LCA

LCA History – early years 1960-1990

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>First calculations of Cumulative Energy Requirements for the production of chemical intermediates and products</td>
</tr>
<tr>
<td>1969</td>
<td>Comparison of Coca-Cola beverage containers (refillable bottles, cans, plastic bottle) quantifying resources and environmental release</td>
</tr>
<tr>
<td>1975</td>
<td>EPA decided in 1975 that using LCA as a regulatory tool was impractical</td>
</tr>
<tr>
<td>1976</td>
<td>Article on Coca-Cola packaging study published in Science (April 9 issue)</td>
</tr>
<tr>
<td>1980</td>
<td>Report concerning major commodity of raw materials made public by the Solar Energy Research Institute</td>
</tr>
<tr>
<td>1984</td>
<td>EMPA (Swiss Federal Laboratories and Material testing) published Ecological report of packaging material and a report that presented a comprehensive list of data needed for LCA; first impact assessment method based on critical volumes introduced</td>
</tr>
<tr>
<td>1990</td>
<td>Adoption of the term LCA “Life Cycle Analysis&quot; in a workshop of the Society of Environmental Toxicology and Chemistry (SETAC) replacing the historical term REPA (resource and environmental profile analysis)</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>1992</td>
<td>Creation of SPOLD in Sweden (later to become the ecoinvent data format)</td>
</tr>
<tr>
<td>1992</td>
<td>First formal framework for the impact assessment phase</td>
</tr>
<tr>
<td>1992</td>
<td>First complete presentation of LCA methodology in a peer reviewed scientific journal in the US</td>
</tr>
<tr>
<td>1993</td>
<td>Publication of inventory guideline document by US EPA</td>
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<tr>
<td>1993</td>
<td>SETAC Code of Practice published to harmonize LCA framework, terminology and methodology</td>
</tr>
<tr>
<td>1994</td>
<td>LCA becomes a part of policy documents and legislation</td>
</tr>
<tr>
<td>1997</td>
<td>First series of LCA ISO standards published (14040-14043)</td>
</tr>
<tr>
<td>1997</td>
<td>I’m attending my first LCA class at TU Berlin, Germany</td>
</tr>
<tr>
<td>1999</td>
<td>Idea on consequential LCA emerged</td>
</tr>
</tbody>
</table>
## LCA History – 2000...

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>UNEP-SETAC Life Cycle Initiative launched</td>
</tr>
<tr>
<td>2003</td>
<td>European Commission underlined the importance of life cycle assessment and the need for promoting the application of life cycle thinking among the stakeholders of IPP</td>
</tr>
<tr>
<td>2006</td>
<td>A framework for Life Cycle Sustainability Analysis proposed</td>
</tr>
<tr>
<td>2006</td>
<td>Feasibility study on social LCA</td>
</tr>
</tbody>
</table>

A good read on the US perspective covering the period from 1970 to 1990:

LCIA (modern) History

- Eco-Indicator 99 (Netherlands)
- IMPACT 2002+ (Switzerland)
- CML (Netherlands)
- EcoScarcity2006 (Switzerland)
- LUCAS (Canada)
- EcoScarcity2013 (Switzerland)
- IMPACT World+ (Canada, USA, Denmark, France, Switzerland)

2000: EPS2000 (Sweden), Jepix (Japan), LIME (Japan)
2002: TRACI (USA)
2003: ReCiPe (Netherlands)
2004: EDIP2003 (Denmark)
2006: LIME 2.0 update (Japan)
2007: TRACI 2.0 update (USA)
2009: LIME 2.0 update (Japan)
2010: LIME 3.0 update (Japan)
2011: TRACI 2.0 update (USA)
2012: ILCD (EU)
2014: IMPACT World+ update (Canada, USA, Denmark, France, Switzerland)
Future trends in LCA
Life Cycle Impact Assessment (LCIA)
From local to global representativeness

Impact World+
From generic to local specificity

Global Warming
Ozone Layer depletion

Aquatic and terrestrial acidification
Photochemical ozone formation
Aquatic and terrestrial Eutrophication

Human toxicity
Ecotoxicity

Land Use
Water Use
Biotic and abiotic resources use

Global Impacts, independent from emission site

Regional and local impacts with strong dependency on emission site
IMPACT World+ Framework

Groups of midpoint categories

- Human toxicity
- Photochem. oxydation
- Ozone layer depletion
- Global warming
- Ecotoxicity
- Acidification
- Eutrophication
- Water use
- Land use
- Resource use

Outputs
- Pesticide
- PM$_{2.5}$
- Cu
- CO$_2$
- Phosphate ...

Inputs
- Water well
- Arable land
- Crude Oil
- Iron ore ...

And hundreds more...

Endpoint

- Human health
- Ecosystem quality
- Resources & ecosystem services

(optional reporting categories)

Climate change
Water impacts

Resources & ecosystem services
<table>
<thead>
<tr>
<th>Outputs</th>
<th>Midpoint</th>
<th>Endpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide</td>
<td>Respiratory effects</td>
<td>Human health</td>
</tr>
<tr>
<td>Diesel</td>
<td>Photochem. oxydation</td>
<td>Ecosystem quality</td>
</tr>
<tr>
<td>Cu</td>
<td>Ozone layer depletion</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>Ionizing radiation human health</td>
<td></td>
</tr>
<tr>
<td>Phosphate</td>
<td>Ionizing radiation aqua. ecosyst.</td>
<td></td>
</tr>
<tr>
<td>Phosphate</td>
<td>Ionizing radiation mar. ecosyst.</td>
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<td>...</td>
<td>Human Tox Cancer</td>
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<td></td>
<td>Human Tox non cancer</td>
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<tr>
<td></td>
<td>Aquatic Ecotox</td>
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<td></td>
<td>Terrestrial Ecotox</td>
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<td></td>
<td>Marine Ecotox</td>
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<tr>
<td></td>
<td>Global warming</td>
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<td></td>
<td>Water use (human health)</td>
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<td></td>
<td>Water use (terr. ecosystems)</td>
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<td></td>
<td>Water use (aqua. ecosystems)</td>
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<tr>
<td></td>
<td>Water use (eco. Serv. and Ress.)</td>
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<tr>
<td></td>
<td>Terrestrial Acidification</td>
<td></td>
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<tr>
<td></td>
<td>Aquatic Acidification</td>
<td></td>
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<tr>
<td></td>
<td>Terrestrial Eutrophication</td>
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<tr>
<td></td>
<td>Aquatic Eutrophication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marine Eutrophication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land use (biotic prod.)</td>
<td></td>
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<tr>
<td></td>
<td>Land use (species loss)</td>
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</tr>
<tr>
<td></td>
<td>Land use (aqu. rech.)</td>
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<td>Land use (carbon seq.)</td>
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<td>Land use (albedo)</td>
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<tr>
<td></td>
<td>Land use (erosion reg.)</td>
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<tr>
<td></td>
<td>Land use (filtration cap.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abiotic ressource use</td>
<td></td>
</tr>
</tbody>
</table>

And hundreds more...
IMPACT World+ the first regionalised LCIA method

Global default Method: IMPACT World +

Continental versions of the method:

- Country level CFs
- Fine resolution CFs
IMPACT World+: a new LCIA method

- Covers the whole world
- Accounts for regional specificity
- Provides explicit estimates of uncertainty and spatial variability
- Includes water use impacts
- Allows for “extraction” of footprint information
- …
Uncertainty Assessment and management
Probability-based LCA: hand dryer

XLERATOR Dryer
10s.

Function: dry hands

Conventional Dryer
30s.

Functional Unit:
260,000 pairs of hand dried

Objective:
Compare the climate change impact of three types of hand dryers

Paper Towels
Probability-based LCA: hand dryer
New tendencies and expansions of classic LCA
Tendencies and expansions of classic LCA

• Social LCA (S-LCA)
• Triple-bottom line sustainability assessment (LCSA)
• Real-time LCA using supply chain data and communication, automated (e.g. via SAP etc.)
• Dynamic LCA: integration of temporal variability
• LCA for territories and organisations
• Planetary boundaries: concept introducing absolute vs. relative sustainability, e.g. for normalisation
Policy and global harmonisation
Consensus and harmonisation

- ISO standardisation
- UNEP-SETAC’s work for global consensus and dissemination
- Harmonisation efforts on EU level (ILCD handbook series and database)
Consensus and harmonisation
Mainstreaming the use of life cycle approaches, increasing the accessibility of cost-effective, robust methodologies and tools based on reliable data and global guidance:

• Sustainability Approaches

• Environmental life cycle impact assessment indicators [Flagship 1b]

• LCA of Organisations [Flagship 1c]

• Data and database management [Flagship 2a]

• Global Principles and Practices for Hotspot Analysis [Flagship 3a]
Drivers for an internationally co-ordinated approach

- Global environmental problems
- Product life cycles are global
- Assure quality and robustness
- Coherent sustainable consumption and production policies and instruments
- Avoid unnecessary costs
- Improve acceptance
- Avoid misleading claims

International Reference Life Cycle Data System (ILCD)

Robust, quality-assured LCAs in the private and public sectors

ELCD Data Network
- Network of consistent and quality-assured LCI data
- Inline with ILCD Handbook
- Open for all to join, providing data under own conditions
- Decentralized with register of available data

ILCD Handbook
- Technical guidance documents inline with ISO 14040 series
- Scope-dependent applications and supporting tools
- Review procedure
- Recommendations for LCIA including factors
- Documentations and nomenclature

NEW: Ecological Footprint for
- Organisations
- Products
European policy (examples)

A resource-efficient Europe – Flagship initiative of the Europe 2020 Strategy, 2011:

Roadmap to a Resource Efficient Europe (2011): common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life-cycle ('environmental footprint').

Building the Single Market for Green Products, 2013:

Commission Communication (2013)196 final and related Recommendation (2013/179/EU) on Product Environmental Footprint and Organisation Environmental Footprint have the objective to “improve the availability of clear, reliable and comparable information on the environmental performance of products and organisations to all relevant stakeholders, including to players along the entire supply chain.”
Labels and certifications using LCA

- Sustainable buildings LEED v4: integration of life cycle thinking, LCA-based data and criteria, points for complete building LCA, ...

- French Grenelle: obligatory, LCA-based labelling of consumer products for impacts on:
  1. Climate change
  2. Water impacts (pollution and consumption)
  3. Biodiversity
Footprint or LCA?
Why LCA?

“If you cannot measure it, you cannot improve it”
(Lord Kelvin)
**Sustainable decisions: Avoid problem shifting!**

<table>
<thead>
<tr>
<th>Shifting</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>in <em>time</em></td>
<td>Recycling products containing heavy metals</td>
</tr>
<tr>
<td>in <em>space</em></td>
<td>Exporting hazardous waste</td>
</tr>
<tr>
<td>to other <em>substances</em></td>
<td>Replacing zinc gutters with PVC gutters</td>
</tr>
<tr>
<td>to other <em>compartments</em></td>
<td>Incinerating waste containing heavy metals</td>
</tr>
<tr>
<td>to other <em>problems</em></td>
<td>Reducing acidifying emissions by increasing GHG</td>
</tr>
<tr>
<td>to other <em>consumption pattern</em></td>
<td>Spending automobile savings on plane travel</td>
</tr>
<tr>
<td>Cancelling out <em>efficiency</em> gains by</td>
<td>Using ever more powerful automobiles even if more</td>
</tr>
<tr>
<td>increasing size</td>
<td>efficient</td>
</tr>
<tr>
<td><em>Prioritizing</em> actions with a limited scope*</td>
<td>Using expensive technologies to treat contaminated soil</td>
</tr>
</tbody>
</table>
Environmental assessment & LCA

- LCA
- Energy balance
- Risk assessment
- Carbon footprint
- Water footprint

Life Cycle stages (Cradle to grave)

Environmental criteria (impacts, resource depletion, ecotoxicity ...)

Cradle to grave

All potential impacts

MJ

Risk assessment

Industrial site

Cradle to grave

All potential impacts

CO₂-eq

Carbon footprint

Water footprint

m³ VW (Virtual Water)
Isn’t climate change a proxy for all impact categories anyway?

Excursus: The concept of “Spaceship Earth”

Buckminster Fuller “Operating Manual for Spaceship Earth” (1963):

• Earth is a spaceship and we are all astronauts.
• Earth as a “mechanical” vehicle that requires maintenance, otherwise it will malfunction.
• The sun is our only energy source.
• We cannot re-supply the resources we have on board.

Marshall McLuhan (1965):
“There are no passengers on Spaceship Earth. We are all crew.”
Excursus: The concept of “Spaceship Earth”

Who are the pilots?

Cockpit of a space shuttle

Cockpit of planet Earth

[Image of space shuttle cockpit and planet Earth cockpit with question mark]
Thank you for your attention!
Thank you very much!

research group for environmental life cycle sustainability assessment