Engineering sustainability – the need for eco-efficiency and eco-effectiveness

Michael Hauschild
Technical University of Denmark
Outline

• Sustainability challenge
• Eco-efficiency and LCA
• LCA today
  – ILCD and PEF
  – Recent developments
• Eco-efficiency and eco-effectiveness
The sustainability challenge

\[ I = P \cdot A \cdot T = \text{Pop} \cdot \frac{\text{GDP}}{\text{person}} \cdot \frac{I}{\text{GDP}} \]

(Graedel and Allenby, 1995)

• \(I\) is the environmental impact

• \(\text{Pop}\) is the global population

• \(\frac{\text{GDP}}{\text{person}}\) is the Affluence, the material standard of living

• \(\frac{I}{\text{GDP}}\) is the Technology factor – environmental impact per created value
The sustainability challenge

\[ I = Pop \cdot \frac{GDP}{\text{person}} \cdot \frac{l}{GDP} \]

- The global population may level off around 10 billion
- Material standard of living will grow strongly in newly industrialised countries (Asia, South America)
- The environmental impact already exceeds sustainable levels in many areas
- So what is the challenge?
Factor 4, 10 or 20

\[ \frac{l}{GDP} \]

The technology factor, \( \frac{l}{GDP} \), is \( l = \text{Pop} \cdot \frac{GDP}{\text{person}} \cdot \frac{l}{GDP} \)

- the impact caused by our creation of wealth and economic value

must decrease 4-20 times in order to

• counterbalance the expected growth in population and material standard of living

• achieve the needed reduction in the environmental impact

...i.e. be environmentally sustainable
Eco-efficiency

Eco-efficiency is the “environmental price” of obtaining a service, meeting a need, creating a value

\[
\text{Eco-efficiency} = \frac{\text{Delivered service}}{\text{Environmental impact}} = \frac{1}{T}
\]

Eco-efficiency is the reciprocal of the technology factor in the IPAT equation

Eco-efficiency means creating more with less
Quantifying eco-efficiency

- LCA focuses on a functional unit – provided service
- LCA quantifies environmental impacts per delivered service

→ LCA is the tool to quantify eco-efficiency
International status of LCA

Framework and principles standardised by ISO in the 1990’ies in the ISO 14040 series

Accompanied by standards on applications (ecodesign, ecolabelling, carbon footprint, ...)

Widely adopted by industry and authorities in full or streamlined versions

Global consensus building under the UNEP-SETAC Life Cycle Initiative 2002-

Central position as decision support tool in EU’s strategy for sustainable Consumption and Production
The European ILCD Guidelines

Launched 12 March 2010 in Brussels

http://www.buildup.eu/publications/9100
From ILCD to PEF methodology

• Dec. 2010 European Council asked EU Commission to "develop a common methodology on the quantitative assessment of environmental impacts of products, throughout their life-cycle, in order to support the assessment and labelling of products".

• April 2013 Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations
  – Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF)
  – Three year testing period (on-going)
  – Development of Product category rules for further streamlining
Intended fields of application

• Communication of life cycle environmental performance information for products
  – product declarations, websites, apps, ...
  – schemes related to environmental claims
• Development of criteria for ecolabels

... but also

• Optimisation of processes along the life cycle of a product
• Support of product eco-design

Recommendation 2013/79/EU
Recent developments in LCA

• Stronger focus on buildings and biomaterials in applications
  – New impact categories land use and water use
  – Carbon footprint
• Continued improvement in databases offering both average data and marginal data
• UNEP-SETAC flagship project on Global guidance on life cycle impact assessment
Recent developments in LCA

• Spatial differentiation highly relevant for many non-global impact categories

Dong Y, Rosenbaum RK, Hauschild MZ: Assessment of metal toxicity in marine ecosystems - Comparative Toxicity Potentials for nine cationic metals in coastal seawater. ES&T submitted 2014
Recent developments in LCA

• Damage modelling taking us from midpoint to endpoint

Relative and absolute sustainability

Eco-efficiency offers us **relative sustainability** ("more sustainable than...")?
- Avoid sub-optimization by considering all impacts and the whole life cycle

Absolute sustainability ("sustainable")?
- Many interpretations of the Brundtland Commission’s definition of sustainability
- Difficult to say what is sustainable in absolute terms
Efficiency and effectiveness

• Doing the things right or doing the right things?
• *(eco)*efficiency: reaching the goal causing minimal environmental impact
• ... but is it the right goal?
• ... what about rebound effects where increased efficiency may lead to increased consumption?
• ... where are the boundaries for sustainability?
The limits of the Earth

Planetary boundaries

Rockström et al., 2009
Absolute sustainability boundaries?

Pre-industrial level

1950 -now

Safe operating space

Rockström et al., 2009
Engineering sustainability

We need to combine eco-efficiency and eco-effectiveness

- Target solutions that are sustainable also in absolute terms
- All technologies and products have a life cycle – analyse it to avoid problem shifting, and include all relevant environmental impacts
- Benchmark the solutions on their eco-efficiency
- Relate improvement to absolute boundaries, considering rebound effects
- **Do the right things right** – employing the highest eco-efficiency towards achieving a sustainable solution
- Remember that sustainability also has a social and an economic dimension
Contact

Michael Z. Hauschild, PhD
Professor, head of division
Quantitative Sustainability Assessment, MAN-QSA
DTU Management Engineering

Technical University of Denmark
Department of Management Engineering
Produktionstorvet
Building 424
2800 Kgs. Lyngby
Direct +45 45254664
mzha@dtu.dk
www.qsa.man.dtu.dk/English.aspx