Life Cycle Assessment with focus on the automotive industry

Prof. Dr. Matthias Finkbeiner

GIZ Lecture Series: LCA in the Automotive Industry
Shanghai * Hefei * Beijing - September 2013

Technische Universität Berlin
Department of Environmental Technology
Chair of Sustainable Engineering

Agenda

• Introduction to Life Cycle Assessment
  – Motivation
  – Method
  – Application
• Life Cycle Assessment in the automotive industry
  – State-of the art and application
  – Challenges
  – E-Mobility
• Perspectives for cooperation
  – Chair of Sustainable Engineering at the Technische Universität TU Berlin
  – Cooperation options
Towards the fundamental question...

- We all agree that we want to protect the environment!
- We all agree that sustainable development is the way to go!

“Our world has enough for each person's need, but not for his greed.”

Mahatma Gandhi

It ain’t easy being green....

environmental problem, e.g. carbon footprint

car

environmental problem, e.g. water footprint of biofuel
The fundamental questions

- How can we measure what is green (environmentally preferable)?
- How can we measure what is blue (more sustainable)?

→ for products
→ for processes
→ for organisations
→ for nations

- If we know the green and blue, how can we make it happen?

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Overview Life Cycle Assessment (LCA)

**Input**
- Energy
  - electrical
  - mechanical
  - thermal
- Raw materials
- Intermediates
- Auxiliaries

**Output**
- Waste
- Waste Water
- Waste Heat
- Co-Products
- Emissions into:
  - Air
  - Water
  - Soil

**Pipeline**
- LCA (ISO 14040, -44, -47, -48, -49)
- TF CR, TF Organisations
- Carbon footprinting

**International Standards of the ISO 14000 series**
- LCA (ISO 14040, -44, -47, -48, -49)
- TF CR, TF Organisations
- Carbon footprinting
Consistent Roadmap: Maslow’s Pyramid adapted to environmental and sustainability assessment

= Life Cycle Sustainability Assessment
= LCA + LCC + SLCA

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Applications of LCA

- products
- technical processes
- organizations

<table>
<thead>
<tr>
<th>Product(s) Process(es)</th>
<th>existing</th>
<th>new</th>
</tr>
</thead>
<tbody>
<tr>
<td>one hot spot analysis (optimisation)</td>
<td>design optimisation</td>
<td></td>
</tr>
<tr>
<td>more than one with the same function</td>
<td>choice optimisation</td>
<td>design optimisation choice</td>
</tr>
</tbody>
</table>

Lesson learnt: there is no one size fits all LCA

In the past:

- „Whatever the problem is, LCA is gonna fix it.“
- One big, costly LCA to be used for everything, i.e. comparison, optimisation, communication, etc.
- Often no clear result and disappointment, „it depends“

Today:

- Goal and application dependant LCAs
- The better defined the question to answer is, the better the LCA result.
- LCA is not a „religion“ (good or bad?), it is a tool (useful or not useful?).
in practice: evolutions of application areas

LCA for hot spot identification

LCA for process optimisation

LCA for company

LCA for lobbying

LCA for KEPIs DfE

LCA for material comparison

LCA for benchmarking

consequences of application areas - data

LCA for hot spot identification

generic

LCA for process optimisation

specific

LCA for company

company specific

LCA for lobbying

generic, „accepted“

LCA for KEPIs DfE

dev. process specific

LCA for material comparison

supplier specific

LCA for benchmarking

competitor data
application areas - communication

- LCA for hot spot identification
- LCA for process optimisation
- LCA for lobbying
- LCA for KEPIs DfE
- LCA for material comparison
- LCA for benchmarking

Env. Report: We do LCA!
We improved! brochure
maybe labels
behind the scenes
public events
internal communication
internal communication

Recent trend: policy relevance of LCA in the EU

„LCAs provide the best framework for assessing the potential environmental impacts of products currently available.“
EU-Commission - Integrated Product Policy - COM/2003/0302 final

Development of a European methodology for the calculation of products and companies Environmental Footprint
Michele Galantini, policy officer
DG Environment, C1
LCA-based legislation: example RED - Directive (I)

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 April 2009

on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Article 17

Sustainability criteria for biofuels and bioliquids

2. The greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall be at least 35 %.

With effect from 1 January 2017, the greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall be at least 50 %. From 1 January 2018 that greenhouse gas emission saving shall be at least 60 % for biofuels and bioliquids produced in installations in which production started on or after 1 January 2017.

Article 19

Calculation of the greenhouse gas impact of biofuels and bioliquids

LCA-based legislation: example RED - Directive (II)

C. Methodology

1. Greenhouse gas emissions from the production and use of transport fuels, biofuels and bioliquids shall be calculated as:

\[ E = c_0 + c_1 + c_2 + c_3 + c_4 - c_5 - c_6 - c_7 - c_8 - c_9, \]

where

- \( E \) = total emissions from the use of the fuel
- \( c_0 \) = emissions from the extraction or cultivation of raw materials
- \( c_1 \) = annualized emissions from carbon stock changes caused by land-use change
- \( c_2 \) = emissions from processing
- \( c_3 \) = emissions from transport and distribution
- \( c_4 \) = emissions from the fuel in use
- \( c_5 \) = emission saving from soil carbon accumulation via improved agricultural management
- \( c_6 \) = emission saving from carbon capture and geological storage
- \( c_7 \) = emission saving from carbon capture and replacement and
- \( c_8 \) = emission saving from excess electricity from cogeneration.
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LCA at Volkswagen

Environmental Protection over the entire Life Cycle

Volkswagen is the high-volume brand that stands for innovation and engineering excellence. Dr. Martin Winterkorn, Chairman of the Board of Management of Volkswagen AG.

In future, we will develop each model in such a way that, in its entirety, it presents better environmental properties than its predecessor. As we do so, we will make sure that improvements are attained over the entire product life cycle.
Followers catching up….

- LCA teams are growing
- management attention is growing
- decision relevance is growing
- relevant topics are growing (e-mobility, CFRP, ...)
- supplier involvement is growing
LCA at Volkswagen

Time and resource demand for LCA of cars

Starting position in 2000

Time and resource demand for LCA of cars

Situation today
LCA of a car

- > 40,000 unit processes
- > 2000 inputs and outputs
- customized software and databases

Example LCA of a car

Finkbeiner et al. (2002): „Life Cycle Design – Methods, Procedures and Examples for the Application of LCA in the Automotive Product Development Process“; 5th International Conference on ECOBALANCE, Japan
LCA of a car

- Prof. Matthias Finkbeiner
- GIZ Lecture Series: LCA in the Automotive Industry

![Diagram showing primary energy demand for different car components]

**LCA for material decisions**

- LCA is the state-of-the-art tool to provide environmental decision-making support.
- It looks at all aspects of a material choice (production, use, end-of-life)

Ruhland et al.: „Process and tools to support Design for Environment at Mercedes Car Group“
4th International Automobile Recycling Congress, Geneva, 10.03.-12.03.2004

![Diagram showing project organisation and team structure]

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18.09.2013
Example Mercedes: Comparison front-end module

Graph 1:
- **Gewicht [kg/Bauteil]**: Weight [kg/component]
- **Aluminium**: Blue
- **Stahl**: Green
- **Polyamid**: Yellow

Graph 2:
- **Primärenergiebedarf [MJ]**: Primary energy demand [MJ]
- **Nutzung**: Green
- **Herstellung (Aluminium)**: Purple
- **Herstellung (Stahl)**: Yellow
- **Herstellung (Kunststoff)**: Orange

Mercedes-Benz: Environmental Certificate C-Class

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Lightweighting does not necessarily mean an environmental improvement

Environmental Burden
- Energy Demand,
- CO₂-Emissions,
- SO₂-Emissions,
- ...

Maximum lightweight design - large overall env. burden

Conventional vehicle

Intelligent lightweight design - small env. burden

"small car"  "big car"

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Sophistication and method refinement in classical areas of automotive parts LCAs...

- How to model EoL-phase?
  (recycled content vs. EoL-recycling or new approaches)

- How to model use phase?
  - FRVs?
  - non-fuel derived emissions?

- How to model energy supply?
  - renewables?
  - production or consumption mix?

- Data issues
  - e-mobility
  - CFRP
  - other specialties

New challenge: Water Footprint

Stand-alone methods
- Virtual Water
- Water Footprint according to WFN
- Global Water Tool
- Corporate Water Gauge

ISO 14046 (working draft)

LCA methods
- Bayart et al. (2010)
- Boulay et al. (2011a)
- EcoInvent (2011)
- PE International (2011)
- Quantis (2012)
- Brent (2004)
- Bösch et al. (2007)
- Mila i Canals et al. (2008)
- Frischknecht et al. (2009)
- Bayart et al. (2009)
- Pfister et al. (2009)
- Boulay et al. (2011b)
- Veolia (2011)
- Motoshita et al. (2008)
- Pfister et al. (2009)
- Maendly & Humbert (2011)
- Motoshita et al. (2011)
- van Zelm et al. (2011)
- Boulay et al. (2011b)

Impact assessment methods
- for Human health
- Ecosystems

Berger, M. & Finkbeiner, M.
Water Footprinting: How to address water use in LCA? Sustainability 2010, 2.4
Case study just published in ES&T*

- Water footprinting in the automotive industry
  - How much water is consumed in a car’s life cycle?
  - What is the impact of this water consumption?

- Procedure
  - Determine water consumption on an inventory level by means of LCA software and Volkswagen’s LCI data bases
  - Geographical differentiation of water consumption according to import mixes, location of production sites, etc.
  - Selection of methods for impact assessment & determination of regional characterization factors
  - Impact assessment
  - Interpretation


Case Study

- LCI: ~ 80 m³ fresh water

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18.09.2013
OEM publications: Daimler - smart

>> Environmental brochure.

smart fortwo electric drive.

Greenhouse gas emissions

- 20,000
- 15,000
- 10,000
- 5,000
- 0

kg CO₂ eq

Petrol-driven smart
smart fortwo electric drive (EU electricity mix)
smart fortwo electric drive (wind-generated electricity)

Usage (120 Tkm)
Recovery
Manufacturing

Usage stage - 20 %
Lifecycle - 37 %
OEM publications: Renault

[Diagram showing environmental impacts of different vehicle models, including electric, diesel, and gasoline vehicles, with a focus on global warming potential.]
Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles

Troy R. Hawkins, Bhawna Singh, Guillaume Majeau-Bettez, Anders Hammer Strømman

Journal of Industrial Ecology
Volume 17, Issue 1, pages 53-64, 2012

Challenge E-mobility: real world issues - charging and de-charging losses

Abbildung 10: Energiebilanz der Hochvoltbatterie des Mercedes Benz A-Klasse E-Cell in Abhängigkeit von der Umgebungstemperatur in %

Univ.-Prof. Dr. rer. nat. Bernhard Gerzberger
Dr. Werner K. Tober
Institut für Fahrzeugantrieb und Automobiltechnik,
Technische Universität Wien
Challenge E-mobility: real world issues - heating and cooling losses

![Graph showing the impact of temperature on vehicle range](image1)

**Mitsubishi i-MiEV**
- Fuel consumption 0 %
- Innenraumtemperatur 22 °C
- Energiereise 25 km (Abzug)

Testzyklus: Eco-Test

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Range (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+30°C</td>
<td>101</td>
</tr>
<tr>
<td>+20°C</td>
<td>108</td>
</tr>
<tr>
<td>+10°C</td>
<td>88</td>
</tr>
<tr>
<td>0°C</td>
<td>73</td>
</tr>
<tr>
<td>-10°C</td>
<td>66</td>
</tr>
<tr>
<td>-20°C</td>
<td>57</td>
</tr>
</tbody>
</table>

Abbildung 12: Reichweite des Mitsubishi i-MiEV in Abhängigkeit von der Umgebungstemperatur im Eco-Test bei einer Fahrbahnneigung von 0 %

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Challenge E-mobility: Macrolevel-LCA

![Graph showing life cycle GWP by fuel and production](image2)

**Life Cycle GWP (CO2eq.)**

- 1 CV
- 1 Hybrid
- 1 Hybrid / 17 million Hybrids

→ Consequential LCA

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Technische Universität Berlin

- 27.049 students, 5.603 from foreign countries
- 4.500 employees, 319 Professors
- 90 study courses
- 7 faculties
- > 140 million € third party funds
Chair of Sustainable Engineering

- Technische Universität Berlin
  - Faculty III - Process Sciences
    - Department of Environmental Technology
    - Chair of Sustainable Engineering

- Target:
  - Promote a sustainable way of engineering
    - Implement principles of sustainability into daily engineering practice
    - Support the development of sustainable products and processes
    - Provide tools that enable the “measurement” sustainability aspects
  - Teaching of students in sustainability topics

Key facts

- experience of >>100 LCA case studies in a variety of sectors, e.g. Mobility, Building, Food, Energy, Investment goods, Consumer Goods, Services
- Carbon footprint studies for both organisations (scope 3) and products
- Water footprint studies for several industrial products
- Social LCA for several industrial products
- Resource efficiency and availability studies for several companies and industry associations.
- Third party funds about 60% from companies and industry associations and 40% public research grants
- Growth of the group from 4 members in 2008 to more than 20 today.
- interdisciplinary team with >50% female and >30% international members.
ISO TC207 Life Cycle Assessment

Subject: Appointment as ISO/TC 207 Subcommittee 5 Chair

Dear Dr. Finkbeiner,

On behalf of the Chair, member bodies and expert participants of ISO/TC 207 on Environmental Management, I congratulate you on your recent appointment as Chair of ISO/TC 207 Subcommittee 5 on Life Cycle Assessment. The work of Subcommittee 5 has helped build the international reputation and credibility of the ISO 14000 family of standards and is critical to our continued success. As you know, the analytical tools of life cycle assessment are being increasingly used by governments and industry as a decision support in a variety of applications, including resource efficiency, environmental labeling or carbon footprinting initiatives.

Thanks again for your leadership and support. I look forward to working with you over upcoming years to ensure ISO’s 14000 series standards remain rigorous, relevant and timely.

Sincerely,

[Signature]

ISO Chairman TC207/SC5 Life Cycle Assessment
Chairman Advisory Committee TC207 seit Juni 2008 in Bogota

UNEP Project Leader Carbon Footprinting

Mr. Matthias Finkbeiner,

The UNEP/SETAC Life Cycle Initiative (http://lciinitiative.unep.fr) is a global Initiative which aims “to bring science-based life cycle approaches into practice worldwide”. Since 2002 the world has experienced a positive evolution regarding the internalization of Life Cycle Thinking in policy making and business. Today key players in sustainable decision making issues see the Initiative as a one-stop-shop for approaches and knowledge. One important achievement is the set up of an international Life Cycle Community with more than 1000 members, 40% of which come from developing countries and economies in transition.

We would like to confirm our acknowledgment of your in kind contribution to the activities of the UNEP/SETAC Life Cycle Initiative in special of the areas to “Life Cycle GreenHouseGas Protocol and Carbonfootprint”, which you are leading.

We will be very grateful to continue receiving your support.

Sincerely yours,

Mr Arab Hoballah
Chief, Sustainable Consumption and Production Branch
UNEP-DTIE

Prof. Matthias Finkbeiner
GIZ Lecture Series: LCA in the Automotive Industry
Dear Matthias,

As you may know, the WRI/WBCSD GHG Protocol is launching a new initiative to develop guidelines for product and supply chain greenhouse gas accounting and reporting. We would like to invite you to be a member of the Steering Committee for this important new initiative. We hope you will consider this invitation, and we would be very grateful to have your input and leadership in this venture.

Margaret Flaherty
Senior Managing Director
World Business Council for Sustainable Development

Manish Bapna
Executive Vice President & Managing Director
World Resources Institute

Margaret Flaherty
Manish Bapna
Collaborative Research Center (CRC) 1026

**CRCs in general**

- The DFG (German Research Foundation) is the self-governing organisation for excellent science and research in Germany.
- Collaborative Research Centers are high-profile institutions established at universities for up to 12 years that enable researchers to pursue an outstanding research programme, crossing the boundaries of disciplines, institutes and faculties.

**CRC 1026 Sustainable Manufacturing**

- 22 Chairs
- 17 subprojects
- close to 11,000,000€ funding for the first 4 years
- plus Integrated Research Training group incl. 35 one year doctoral scholarships
**Labo**ratory for Sustainable **M**anufacturing

**Source:** TUB

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Integrated Research Training Group

Doctoral Scholarships

Reference Number: SFB-1026-MGK-12-1
Topic: Short term doctoral scholarships in the Integrated Research Training Group of the Collaborative Research Centre CRC 1026

Motivation:
Three one year doctoral scholarships (Euro 1,362.00 per month) will be awarded in April and October 2013.
The scholarships are granted for the participation in the German Science Foundation (DFG) funded Integrated Research Training Group “Sustainable Manufacturing – Shaping Global Value Creation” at the Technische Universität Berlin. The challenge in creating products and technologies which promote social, economical and ecological sustainable production.

- 5 scholarships per year from 2013
- after one year: potentially get researcher position in the CRC or go back to “home university”.

Cooperation options

- informal
  - always welcome
  - limited resources and sustainability
- formal
  - cooperation agreements
  - joint research projects
  - advisory or guest professorship