ETH Lecture „Business and Politics of Climate Change”
25 November 2008

Carbon Footprint of food and personal care products

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Motivation

• Climate change is increasingly recognized as one of the major challenges humankind is facing

• The environmental impact of food production represents a significant share of the overall impact of consumption (see e.g. European EIPRO study)

→ Provide decision-support tools that guide purchasing decisions and provide incentives for environmentally benign food production and consumption
Situation in Switzerland

Some initial climate labels exist:

- Best of class label by Migros (washing detergent, toilette paper, cream)

- By air label by Coop (declaration and offset of CO₂ emissions from air transport)

→ Discussion about further measures is ongoing…
Activities in the rest of the world

- **USA**: Wallmart demands LCA of its suppliers
- **UK**: Carbon Trust Initiative (currently 17 partners, **PAS 2050 standard** for Carbon footprint accounting recently released)
- **France**: environmental product declaration will be mandatory as of 2011 on (implementation not clear yet); some supermarkets state CO2-emissions on products
- **Germany**: pilot project started in 2008 on carbon footprinting and other environmental impacts (dm, FRoSTA, Henkel, Tchibo, T-Home, Tetra Pak; DSM, REWE Group, Tengelmann)
Life Cycle Assessment (LCA): overview

1. Definition of goal and scope
   • What is the purpose of the LCA?
   • Who is the intended audience?
   • What are the systems under study and what are their functions?
   • What are the underlying assumptions / limitations?

2. Inventory analysis
   • What are the relevant emissions and resources the system(s) produce or consume?
   • How are these inputs and outputs allocated to the functions of the systems?

3. Impact assessment
   • Which impact categories are considered and which models are used?
   • What environmental impacts are caused by the emissions and the use of resources from the system(s)?
   • How is aggregation performed?

ISO 14040, 14044

4. Interpretation
   • What are the conclusions?
   • How reliable and sensitive are the results?
   • What are the recommendations?
Life Cycle Assessment

- Resources
- Disposal
- Transport
- Production
- Use
- Emissions
Global value chains
Life Cycle Inventory databases

More than 4,000 processes
Approx. 150 resource uses
Approx. 850 emissions

→ Many processes about energy generation, transport, basic materials, waste treatment etc.
→ only some food and consumer products
Life Cycle Impact Assessment

### Inventory Analysis

<table>
<thead>
<tr>
<th>Emission/ Unit Resource</th>
<th>Compartment</th>
<th>Amount per funct. unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ kg</td>
<td>Luft</td>
<td>0.5</td>
</tr>
<tr>
<td>CH₄ kg</td>
<td>Luft</td>
<td>1.5</td>
</tr>
<tr>
<td>SOₓ kg</td>
<td>Luft</td>
<td>1.0</td>
</tr>
<tr>
<td>NOₓ kg</td>
<td>Luft</td>
<td>0.5</td>
</tr>
<tr>
<td>Cd²⁺ kg</td>
<td>Wasser</td>
<td>0.0001</td>
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<tr>
<td>Fe kg</td>
<td>Boden</td>
<td>0.5</td>
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</table>

### Life Cycle Impact Assessment

#### Global Warming

<table>
<thead>
<tr>
<th>Emission</th>
<th>Characterization factor</th>
<th>Ref. unit</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>1</td>
<td>0.5</td>
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<tr>
<td>CH₄</td>
<td>23</td>
<td>34.5</td>
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<tr>
<td>Sum</td>
<td></td>
<td>35.0</td>
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</table>

#### Acidification

<table>
<thead>
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<tbody>
<tr>
<td>SOₓ</td>
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<tr>
<td>NOₓ</td>
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<td>0.35</td>
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<tr>
<td>Sum</td>
<td></td>
<td>1.35</td>
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</table>

#### Human Toxicity

<table>
<thead>
<tr>
<th>Emission</th>
<th>Characterization factor</th>
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<tbody>
<tr>
<td>NOₓ</td>
<td>1.4</td>
<td>0.065</td>
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<tr>
<td>Cd²⁺</td>
<td>23</td>
<td>0.00023</td>
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<tr>
<td>Sum</td>
<td></td>
<td>0.35023</td>
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Example: food consumption

- Ongoing study performed for Food Retailer
- Used in purchasing decisions of retailer
- May be used for ecological marketing in the future
- Consumer information
Assessing the impact of food consumption

- seedling production
- land use
- farm machinery work
- fertilizer
- pesticides and flame treatment
- irrigation
- freight ship, lorry, airplane
- heating energy
- cooling energy
- washing water

Agricultural production system
- IP or Organic
- Greenhouse or open field production

Vegetables and fruits at the point of sale (package excluded)

Storage Grading Washing Transportation

Emissions into air, soil and water
Vegetables

How does a radish become a radish?

Duration of cultivation, seeds, irrigation water, yield

Fertilizer
Pesticides
Electricity and further material

Functional unit:
1 kg of vegetable
Global warming potential („Carbon footprint“)

Total amount in CH, 1000 t

<table>
<thead>
<tr>
<th>Item</th>
<th>CO₂-equivalents, 1000 t</th>
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</thead>
<tbody>
<tr>
<td>Green asparagus</td>
<td>50</td>
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<tr>
<td>Cucumber</td>
<td>50</td>
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<tr>
<td>Tomatoes</td>
<td>50</td>
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<tr>
<td>Carrots</td>
<td>50</td>
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<tr>
<td>Radish</td>
<td>50</td>
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<td>Eggplant</td>
<td>50</td>
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<td>Fennel</td>
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<td>Cauliflower</td>
<td>50</td>
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<tr>
<td>Broccoli</td>
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<td>Zucchini</td>
<td>50</td>
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<tr>
<td>Salad</td>
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<tr>
<td>Onions</td>
<td>50</td>
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<tr>
<td>Cabbage</td>
<td>50</td>
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<tr>
<td>Celery</td>
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<tr>
<td>Spinach</td>
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Global warming potential of asparagus

White asparagus

Green asparagus

Avoid transport by airplane
Vegetables with a large improvement potential

- cucumber
- radish
- tomato

Avoid heated greenhouse production

Not in accordance with guidelines

GH: greenhouse production

→ avoid heated greenhouse production
Example: Carbon footprint of tomatoes (seasonal variation)

GWP of 1 kg of Tomatoes from Various Countries

kg CO$_2$-equivalents / kg

Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Carbon footprint

Tomatoes, cucumbers and radish from non-heated production; green asparagus not transported by plane

<table>
<thead>
<tr>
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<tr>
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<td>Spinach</td>
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<table>
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<th>Improvement potential</th>
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<td>Spinach</td>
<td></td>
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<tr>
<td>Radish</td>
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</table>
Lowering the Carbon footprint of vegetables

1. Avoid air transport
2. Prefer non-heated production over heated greenhouses
3. As little truck transport as necessary
Assessing the impact of food consumption

- seedling production
- land use
- farm machinery work
- fertilizer
- pesticides and flame treatment
- irrigation
- freight ship, lorry, airplane
- heating energy
- cooling energy
- washing water

Agricultural production system
- IP or Organic
- Greenhouse or open field production

Vegetables and fruits at the point of sale (package excluded)

Storage
Grading
Washing
Transportation

Emissions into air, soil and water
Example: Carbon footprint of apples and kiwis (seasonal variation)
Lowering the Carbon footprint of fruits

1. Avoid air transport
2. Storage is relevant, but better than overseas transport (even if by ship)
3. Pesticide application relevant in cases (desinfection of soils)
Environmental impact categories

- Climate change
- Resource depletion
- Land use
- Water use (X)
- Human toxic effects
- Ozone depletion
- Photochemical ozone creation
- Ecotoxic effects
- Eutrophication
- Acidification

Areas of protection:
- Resources
- Human Health
- Natural Environment
For many products GW emissions are not a bad surrogate indicator of overall environmental impact

Example: correlation analysis of 430 materials (ecoinvent)

For food products other environmental impacts also important (land and water use)! … avoid problem shifting!

Huijbregts et al. 2008
Example: Global virtual water flows of agricultural products

Regional virtual water balances and net interregional virtual water flows related to the trade in agricultural products (period: 1997-2001)

Chapagain & Hoeskstra, 2004
Freshwater use assessment

Consumptive use
Degradative use
In-stream storage

Resource depletion
Ecosystem health
Human health

UNEP/SETAC Life Cycle Initiative: Project on Water Use Assessment
Example: water-use impact of vegetable production compared to total environmental impact (Eco-indicator 99)

<table>
<thead>
<tr>
<th>Impact share of water consumption</th>
<th>Spain</th>
<th>China</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected watershed</td>
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<td></td>
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</tr>
<tr>
<td>Onion</td>
<td>&gt;30%</td>
<td>&gt;50%</td>
<td>&gt;20%</td>
</tr>
<tr>
<td>Tomato</td>
<td>&gt;35%</td>
<td>&gt;40%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td>Potato</td>
<td>&gt;40%</td>
<td>&gt;30%</td>
<td>&gt;35%</td>
</tr>
<tr>
<td>Pepper</td>
<td>&gt;50%</td>
<td>&lt;15%</td>
<td>&gt;35%</td>
</tr>
<tr>
<td>Cabbage</td>
<td>&gt;30%</td>
<td>&gt;40%</td>
<td>&gt;40%</td>
</tr>
</tbody>
</table>

Ph.D. thesis Stephan Pfister
**Carbon footprint of meals**

**Maharadscha-Rösti**

**Für 4 Personen**
- 1½ kg festkochende Kartoffeln
- 2 rote Chili, entkernt, fein gehackt
- 2 Knoblauchzehen, fein gehackt
- ½ Bund Koriander, fein gehackt
- 3 cm Ingwer, geschält, fein gehackt
- 4 TL Fine Food Delhi Curry
- 2 TL McCormick Gewürzmischung Thailand 7-Spice
- 1 TL Salz
- wenig Pfeffer
- 2 EL Erdnussöl

Kartoffeln schälen und an der Röstiform direkt in eine Schüssel reiben. Chili und alle Zutaten bis und mit Pfeffer beigeben, mischen. Öl in einer beschichteten Bratpfanne heiss werden lassen, Hitze reduzieren. Kartoffelmasse in 8 Portionen teilen, portionenweise in die Pfanne geben, zu Küchlein flachdrücken, bei mittlerer Hitze beidseitig ca. 8 Min. knusprig braten.

**Dazu passen:** gebratene Entenbrust

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**Ratatouille - Tiptopf**

Für 4 Personen
- ½ EL Öl/Butter
- 1-2 kleine Knobli
- Thymian
- Majoran
- Basilikum
- Bohnenkraut
- 600 g Gemüse: Zucchetti, Tomaten, Aubergine, Peperoni
- wenig Salz oder Streuwürze

Würzen, zudecken und auf grosser Stufe erwärmen bis es zischt. Sofort auf kleine Stufe zurück schalten. Während 20-30 min dämpfen.

Reibkäse dazu servieren.
Carbon footprint of meals (base scenario)

- Total
- Disposal
- Storage
- Home preparation
- Transport to household
- Transport retailer
- Package
- Production

GWP [kg CO₂-Eq.]

- Rösti - 4 Mt. storage
- Ratatouille
LCA of wine

- Functional unit: 1 bottle of wine (0.75 l)
- ecoinvent v2.01 → Transport, energy, fertilizer, pesticides, chemicals
Carbon footprint of Swiss and Californian wine

- **Wine California:**
  - Irrigation
  - Transport
  - Package
  - Wine cellar

- **Wine Switzerland:**
  - Transport
  - Package
  - Wine cellar
  - Production

![Bar chart showing the carbon footprint of Swiss and Californian wine](chart.png)

- **Key:**
  - Diesel
  - Disposal
  - Glass production
  - Phenol
  - Cork
  - Fertilizer (Mg-Sulfat)
  - Transport truck
  - Transport ship
  - Irrigation
  - Other
Water use Wine
Conclusions wine study

1. In the case of overseas transport, the wine bottling should be done at the site of consumption

2. Wine from regions with enough precipitation (otherwise watch irrigation amounts)
Comparing the Environmental Footprint of Cleaning Products: The Relevance of Different Life Cycle Phases
Goals of the Study

• Investigate the ecological relevance of different life cycle phases of nine home care and personal hygiene products
  • Bathroom, kitchen and window cleaning agents (3)
  • Detergent boosters, liquid special and color powder detergents (3)
  • Liquid and bar soaps (2)
  • WC care product (1)

• Identify the contribution of different environmental impacts to overall environmental footprint of these consumer products

• Provide guidance to different stakeholders (producers, suppliers, retailers, consumers)
Method

- Comprehensive cradle-to-grave LCA study
- Functional Unit (FU): “one typical application”
  e.g. one-time hand washing, one load of laundry
- Geographical scope: Europe (specific focus: CH, E)
- LCIA:
  - GWP (→ carbon footprint)
  - EI’99 (→ environmental footprint)
  - Ecotoxicity of chemical product components (USEtox model, V 0.994)
  - Freshwater consumption in different LC stages (new method developed at ETH)
System Boundary

LCA model system boundary

Resources (elementary flows)

Upstream processes
- Transports
- Ancillaries and raw materials production
- Energy generation/supply
- Packaging production

Manufacturing

Transport and Storage

Use phase

End-of-life-phase

Downstream processes
- Waste disposal (municipal waste incineration)
- Recycling
- Wastewater disposal (municipal wastewater treatment)

Emissions (elementary flows)

Technosphere

Resources

Ecosphere

Technosphere
Scope and Data Sources

- Life cycle stages
  - Production phase: gate-to-gate industry data; literature data
  - Retail phase: transport and storage data from retailer
  - Use phase: product information and data from consumer-behavior-studies (from industry); mobility study
  - End-of-life-phase: waste incineration incl. energy recovery, landfilling, wastewater treatment

- Background processes: ecoinvent database v2.01
## Scenario modeling

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Retail</th>
<th>Use</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base case</strong></td>
<td>EU production conditions</td>
<td>Transport and storage EU</td>
<td>Typical average application, car transport</td>
<td>Waste incineration (energy recovery)</td>
</tr>
<tr>
<td><strong>Scenarios</strong></td>
<td></td>
<td></td>
<td>• Overdosage</td>
<td>• Landfilling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Water amount</td>
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<td></td>
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<td>• Water temp.</td>
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<td></td>
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<td></td>
<td>• Technology</td>
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<td></td>
<td></td>
<td></td>
<td>• Product type</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>• Vehicle for home transport</td>
<td></td>
</tr>
</tbody>
</table>
Liquid Soap vs. Bar Soap for Hand Washing

Base case

• Functional Unit (FU): “one-time hand washing of approximately 30 seconds”
  • Amount of soap product
    • Bar soap: 0.35 g
    • Liquid soap: 2.3 g
  • Water use for hand washing
    • Bar soap: 0.91 liters (0.24 gal)
    • Liquid soap: 0.64 liters (0.17 gal)
  • Water temperature 38°C (100.4°F)
  • Light fuel oil boiler for warm water supply

• End-of-Life
  • Solid waste incineration of packaging incl. energy recovery
  • Municipal wastewater treatment
Liquid Soap vs. Bar Soap for Hand Washing – I

GWP [kg CO₂-eq/FU]

Base case

Chemical raw materials
Packaging material

Production Retail Use End-of-life Energy recovery

Energy recovery
End-of-life
Use
Retail
Production

Home Transport
Storage
Transport
Foreground
Background

Heat
Electricity
Packaging incineration
Wastewater treatment
Warm water

GWP [kg CO₂-eq/FU]
Conclusions cleaning products

• Production and use phases are most influencing

• Raw chemicals and packaging manufacturing most relevant (production)
  → Producer's choice of chemicals and packaging important

• Consumer behaviour heavily guides overall environmental performance
  → Consumer information extremely important
  → Retailer to promote refill-product offerings

• Fossil feedstock, energy consumption and associated impacts most influencing in all life cycle phases of all products
  → Promotion of renewable energy technologies
Improving the impact of consumption

- Use information in the production phase
- Use of information in purchasing decisions and supply-chain management of retailers
- Ecological marketing
- Online information on products or monthly sustainability report of purchase; Customers may gather eco-points

→ Incentive to consume sustainable products

- Remaining environmental impact of purchase can be compensated → money and technology transfer to the “South”
Thank you!

- Franziska Stössel
- Chris Mutel
- Stephan Pfister
- Caroline Wildbolz
- Annette Köhler
- Several students (Linda Kren, Gregoire Meylan, Claudia Nydegger, Dominik Saner …)

For financial support and data:
Henkel and Coop Sustainability Fonds