Life cycle analysis of bread production
– a comparison of eight different options –

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Questions

• How to produce bread being most environmentally friendly?

• Which of the process steps, including transports, do account for the highest or lowest environmental effects?

• At which processes is it feasible to introduce ecological optimisations or to reduce environmental implications, and what are the corresponding recommendations?
Goal definition

• **Functional unit:**
  1 kg bread ready for consumption at home.

• **System boundaries:**
  Production in Germany. Pre-chains: split worldwide.

• **Others:**
  Basic data, assumptions, allocation issues et cetera: see paper.
## Impact Assessment

<table>
<thead>
<tr>
<th>Environmental impact</th>
<th>Indicator</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource depletion</td>
<td>cumulated non-renewable primary energy</td>
<td>Crude oil, natural gas, mineral coal, lignite, uranium ore</td>
</tr>
<tr>
<td>Greenhouse effect</td>
<td>CO$_2$-equivalents</td>
<td>CO$_2$, N$_2$O, CH$_4$</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>N$_2$O</td>
<td>N$_2$O</td>
</tr>
<tr>
<td>Acidification</td>
<td>SO$_2$-equivalents</td>
<td>SO$_2$, NO$_x$, NH$_3$, HCl</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>PO$_4$-equivalents</td>
<td>NO$_x$, NH$_3$</td>
</tr>
<tr>
<td>Photo smog</td>
<td>Ethene-equivalents</td>
<td>CH$_4$, NMHC</td>
</tr>
<tr>
<td>Land use</td>
<td>ha</td>
<td>ha</td>
</tr>
</tbody>
</table>
Life Cycle of the bread production

- **Seed**
  - Pesticide
  - Fertiliser
  - Fuel

  → **Cultivation**
  → **Grain**
  → **Transport**

- **Fuel oil**
  → **Drying**
  → **Grain**

  → **Flour production**
  → **Flour**
  → **Baking process**

- **Electricity**
  - **Fuel oil**
  - **Natural gas**

→ **Home**
→ **Retailer**
→ **Bread**
Energy demand

baking process:
  = factory

flour production:
  = industrial mill

crop production:
  = conventional
Differentiation of important processes

• **Crop production:**
  conventional ↔ organic

• **Flour production:**
  industrial mill ↔ domestic mill

• **Baking technologies:**
  large bread factory ↔ bakery ↔ domestic bread maker
8 scenarios to produce bread

- conventional
  - industrial mill
    - factory
  - domestic mill
    - home
- organic
  - industrial mill
    - bakery

1. conventional industrial mill factory
2. conventional domestic mill home
3. organic domestic mill home
4. organic domestic mill home
5. organic domestic mill home
6. organic industrial mill home
7. organic industrial mill bakery
8. organic industrial mill factory
Energy demand

MJ/kg bread

- farming
- milling
- baking
- transport

factory  bakery  home
Energy demand

- farming
- milling
- baking
- transport

Conventional farming vs. organic farming

- MJ/kg bread

- Industrial mill
- Domestic mill

- Factory bakery
- Home
Greenhouse effect

- Farming
- Milling
- Baking
- Transport

Conventional farming vs. Organic farming

Bar chart showing the greenhouse effect in g CO2-eqiv./kg bread for different stages of production:
- Industrial mill vs. Domestic mill
- Factory bakery
- Home
Ozone depletion

- Farming
- Milling
- Baking
- Transport

**conventional farming**

- Industrial mill
- Domestic mill
- Home

**organic farming**

- Industrial mill
- Domestic mill
- Home
Land use

- conventional farming
- organic farming

$m^2$/kg bread
LCIA results

- **Energy demand**: MJ/kg bread
- **Greenhouse effect**: g CO₂-eqv./kg bread
- **Ozone depletion**: g N₂O/kg bread
- **Acidification**: g SO₂-eqv./kg bread
- **Eutrophication**: g PO₄-equiv./kg bread
- **Land use**: m²/kg bread

- **Crop production**
- **Milling**
- **Baking**
- **Transport**
Results

- Organically produced grain has to be preferred to grain that was produced conventionally regarding all impact categories except land use.

- Flour may be produced preferably in an industrial mill rather than in a domestic mill.

- Ranking the bread baking process from the most to least advantageous option results in the order: factory, local bakery and domestic bread maker.

- Sensitivity analysis for transportation
Transport by the consumer

- **Conventional crop production**
  - Factory
  - Bakery
  - Domestic mill
  - Retailer
  - Home

- **Organic crop production**
  - Factory
  - Bakery
  - Domestic mill
  - Retailer
  - Home
Assumptions

Basic scenario
• Transport of bread from the bakery: by bicycle.
• Transport of grain, flour or bread from the supermarket: by car without driving detours (on the way from / to work etc.).

Extreme scenario
• Transport of 1 kg of bread, flour or grain by car (4 km round trip).
Sensitivity analysis: transport

- farming
- milling
- baking
- transport

**Scenarios:***
- Extreme scenario
- Bandwidth
- Basic scenario

**Locations:***
- Factory
- Bakery
- Home
Sensitivity analysis: transport

Energy demand

Greenhouse effect

Ozone depletion

Acidification

Eutrophication
Transportation: Break even points

- Energy demand -

MJ/kg bread

<table>
<thead>
<tr>
<th>Location</th>
<th>Farming</th>
<th>Milling</th>
<th>Baking</th>
<th>Transport</th>
<th>Transport Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factory 1</td>
<td></td>
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<td></td>
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<tr>
<td>Factory 2</td>
<td></td>
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</tbody>
</table>

Distances:
- Farming: 0.9 km
- Milling: 0.5 km
- Baking: 0.9 km
- Transport: 4 km

- Extreme scenario
- Basic scenario
- Bandwidth
Transportation: Break even points

- Energy demand -

- farming -  
- milling -  
- baking -  
- transport -  
- transport home -

![Graph showing energy demand comparison between conventional and organic farming.](image)

- conv. farming

- organic farming

- extreme scenario

- band-width

- basic scenario

- 0.2 km

- 4 km
Transportation: Break even points

- Energy demand -
- Acidification -

<table>
<thead>
<tr>
<th></th>
<th>0,2 km</th>
<th>4 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>conv. farming</td>
<td></td>
<td></td>
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<tr>
<td>organic farming</td>
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<table>
<thead>
<tr>
<th></th>
<th>3 km</th>
<th>4 km</th>
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<td></td>
<td></td>
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<tr>
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<td></td>
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</tbody>
</table>

- farming - milling - baking - transport - transport home
Results

Advantages and Disadvantages of each processing step:

- **Farming:** Organic ↔ Conventional
- **Milling:** Industrial mill ↔ Domestic mill
- **Baking:** Bread factory ↔ bakery ↔ Domest. bread maker

For the ultimate appraisal the **transport** of grains, flour or bread respectively, by the consumer is of evident importance.
Recommendations

If land use is more important than all the other environmental impact categories:

Signals: grain from conventional farming has to be preferred to grain that was produced organically

If land use is of minor relevance compared to saving of resources, greenhouse effect, ozone depletion, acidification and eutrophication:

Signals: grain from organic farming has to be preferred to grain that was produced conventionally
Recommendations

Bread factories / Supermarkets

• Use cereals from organic production.

• Mount campaigns, that customers buy as much as possible at once and if possible without driving detours (buy on the way from / to work etc.).

Bakeries

• Use cereals from organic production.

• Optimise the energy demand.

• Mount campaigns, that customers don`t use the car to buy bread.
Recommendations

Consumer

• Buy bread from organically grown cereals in a supermarket.
  - If bread from organic grain is not available in the supermarket, customers have to ask for it to increase the demand and ...
  - ... buy it in a bakery.

• If baking at home, cereals from organic production and flour from industrial mills have least environmental implications.
  - Use a domestic bread maker instead of an oven.
  - If an oven is used, increase the degree of utilisation.

• Don’t use a car to transport bakery products. If a car is used, buy also other groceries and without driving detours (on the way from/to work etc.).
Thank you – mange tak!

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Dr. Markus Quirin