Introduction

Hans-Jörg Althaus

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building materials in ecoinvent

- building materials & processes
  - mineral materials, insulation materials, glass, processes, infrastructure
- wood
  - sawn timber, wooden boards
- metals
  - iron / steel, aluminium, other non-iron metals, processing
- plastics

collectors

- responsible institute: EMPA, Dübendorf
- project leader: Hans-Jörg Althaus
- authors: Daniel Kellenberger, Hans-Jörg Althaus, Frank Werner, Tina Küniger, Mischa Classen
- contributions from: ESU-services
  - Niels Jungbluth
- financial support: BUWAL, BBL, ASTRA, EMPA
Main differences to ÖvE3

- more detailed modelling
- land use
- infrastructure
- multi-output processes
- major methodological changes for wood

Workshop

- mineral building materials (Daniel Kellenberger)
- wooden materials (Hans-Jörg Althaus)
- comparison steel / wood construction (Daniel Kellenberger)
- discussion
0 Content

1 Goal
2 Selection of the Modules
3 Initial Situation
4 Procedure und Results based on the Lime Production Process
5 Problems
6 Outlook
1  Goal

- No products specific data
- Background data for LCA
- Modelling of the production process as transparent as possible
- Unit process on the lowest possible level (>easier implementation of process improvements in future)

2  Selection of the Modules

Data are principally based on existing inventories. If necessary they are completed, some are added. The main product categories are:

- Sand/Gravel/Clinker/Cement/Concrete
- Lime Products
- Brick/Tile/Refractory Bricks
- Glass Products
- Insulation Materials
- Gypsum Products
- Plaster and Mortar
- Infrastructure and Auxiliary Products
3 Initial Situation

- **Scientific Reports**: often aggregated data, with another focus (e.g. emissions) or relation to process not clear
- **Environmental Reports**: often only representation of emissions which must be recorded by law and data which are economically relevant
- **Management ratio**: only economically relevant data
- **Personal Communication**: in most cases useful but not comprehensible
- **Encyclopaedia**: often good description of the product and process but no information on the ecological relevance
- **Survey**: survey into needed data guarantees highest transparency

4 Procedure and Results

**Lime Production Process**

1. Modelling of the production process
2. Analysis of the sub-processes (e.g. mining of limestone)
3. Drawing up a flow chart of the sub-processes
4. Study and illustration of the information
5. Cumulated energy demand and assessment results
Mining of Limestone

![Image of limestone mining site]

Mangement ratio of limestone factory KFN to be analyzed.

Production Process, main Products KFN

- Calcite in ground
- Limestone, at mine
- Limestone, washed
- Quicklime
- Hydrated loose Lime
- Hydrated packed Lime
- Hydrated packed Lime, crushed, washing, calcination
- Hydrated packed Lime, packing

![Diagram of production process]
Flow chart "mining of raw limestone"

### Remarks to Outputs
- 40% of dust emissions as bauxite mining because for 1 kg of bauxite, six times as much has to be mined (2.4 kg / 1000 kg bauxite) for 10 μm > 45% > 2.5 μm
- 10% of dust emissions as bauxite mining because for 1 kg of bauxite, six times as much has to be mined (2.4 kg / 1000 kg bauxite) for 2.5 μm < 0.02 μm
- 20% of dust emissions as bauxite mining because for 1 kg of bauxite, six times as much has to be mined (2.4 kg / 1000 kg bauxite) for 2.5 μm > 0.02 μm

### Remarks to Inputs
- Total amount of mined limestone 2001: 381,028 t; the losses by dust emissions have been neglected.
- Assumption: After 13 years the used land is recultivated
- Foot of drilled hole filled with Tovex und shank filled with Amolit
- Process of transports and drilling: diesel used by all vehicles in the mine (0.26% of the diesel consumption is used for transports concerning recultivation and included in the module "recultivation": 191,123 l, with a density of 840 kg/m³ and a net calorific value of 42.8 MJ/kg
- Includes the total amount of fuel used for heating of mostly administrative buildings
- Input includes infrastructure needed at mine (buildings, access roads, ...); Service life assumption: 50 years, total produced products over 50 years: 19,051,400,000 kg

### Illustration (Allocation and Quantity)

- Allocation and Quantity
- Resource
- Land occupation, mineral extraction site
- Machinery
- Infrastructure (mine)
- Energy consumption
- Share of share of energy consumption for administration
Land-use of limestone mining (KFN)

- 5 mining stages in 65 years
- Mining duration per stage about 13 years (followed by a recultivation of the area)
- Total mining amount in 65 years: 10'280'000 m³
- -> yearly mining amount: 160'000 m³/a
- Average density: 2'300 kg/m³ -> 368'000 t/a
- Total mining area in 65 years: 156'000 m²
- -> yearly mining area: 2'400 m²
- Land-use per kg product: \( \frac{2'400 \text{ m}^2}{368'000'000 \text{ t}} \times 13 \text{ a} = 9.78E-05 \text{ m}^2\text{a} \)
References

1. **Further technological correlation:**
   - Data on related processes, plants, and materials from a single study (i.e., data from all processes of a similar technology, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles).
   - Data are based on estimated figures derived from theoretical considerations, industrial expert; data estimates based on qualified industrial expert; data estimates based on company environmental reports; data estimates based on legislation.

2. **Completeness:**
   - Data on related processes, plants, and materials from a single study (i.e., data from all processes of a similar technology, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles).
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3. **Reliability:**
   - Data on related processes, plants, and materials from a single study (i.e., data from all processes of a similar technology, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles).
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4. **Uncertainty matrix (e.g., Heating Energy):**
   - Data on related processes, plants, and materials from a single study (i.e., data from all processes of a similar technology, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles, OR data on different technology, OR data on different material, OR data on plants but from shorter periods of their operation, OR data on technologies with different investment cycles).
   - Data are based on estimated figures derived from theoretical considerations, industrial expert; data estimates based on qualified industrial expert; data estimates based on company environmental reports; data estimates based on legislation.
Results: GWP und EI 99 (H,A)

Global warming potential (IPCC 2001, GWP 100a)

-2.0E-1
-2.0E-1
4.0E-1
6.0E-1
8.0E-1
1.0E+0
1.2E+0

100kW, non-modulating
diesel, burned in building
machine

Comparison with other source

Comparison of the results from ecoinvent with the results from „Ökologische Bilanzierung von Baustoffen und Gebäuden“ from P. Eyerer and H.-W. Reinhard (*)
5 Problems/Discussion

Uncertainty
- Uncertainty problems are included for the first time in a project in this wide scope.
- The uncertainty matrix is an attempt to determine the uncertainty when data are inadequate for statistics.

Cut-off
- „Waste“ as Input (e.g. waste tyres in cement factory) have no burdens and therefore do not arise in the balance.
- Energy and mass-balances won’t fit (emissions for the example of cement production are collected totally).

6 Outlook

Following points are ideas to improve the inventory within ecoinvent.
- Improving the data situation in co-operation with the industry (product specific data)
- Horizontal aggregated, product-specific data of the “same” product from different manufacturer can be used as basis for general statements.
Wooden Materials

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content

- wooden materials in ecoinvent
- the wood chain in ecoinvent
- data sources
- main differences to ÖvE3
- selected results
**wooden materials in ecoinvent**

- direct forest products (round wood, fuel wood)
- sawn timber (boards, air/kiln dried, raw/planed)
- boards from round wood (plywood, laminated board)
- boards from industrial residue wood (OSB, fibre board)
- fuel (chips, pellets)
- chemical wood protection
- auxiliary modules

**wood chain in ecoinvent**
Wood chain in ecoinvent:

Sawmill:
- Industrial residue wood, softwood, forest debarked, u=70%, at plant

Wood wool production:
- Sawn timber, softwood, raw, air dried, u=20%, at plant
- Sawn timber, softwood, raw, air dried, u=20%, at plant
- Sawn timber, softwood, raw, air dried, u=20%, at plant

Wood wool manufacturing plant, cement bonded boards:
- Wood wool, cement bonded, at plant

Wood chip in ecoinvent:

Glued laminated timber, indoor use, at plant:
- Sawn timber, hardwood, raw, air dried, u=20%, at plant
- Industrial residue wood, GLT production, indoor use, u=10%, at plant
- Industrial residue wood, GLT production, indoor use, u=10%, at plant

Glued laminated timber, outdoor use, production:
- Sawn timber, hardwood, raw, air dried, u=20%, at plant
- Industrial residue wood, GLT production, outdoor use, u=20%, at plant
- Industrial residue wood, GLT production, outdoor use, u=20%, at plant

Laminated timber element, outdoor use, production:
- Industrial residue wood, LTE production, hardwood, u=20%, at plant
- Three layered laminated board, production

Three layered laminated board, production:
- Industrial residue wood, 3-layered LB production, softwood, u=20%, at plant
data sources

- **chips**: BFS/BUWAL 2000, Frischknecht et al. 1996
- **chemical protection**: Künnger et al. 2000, Hillier 1997
- **infrastructure**: expert guess

main differences to ÖvE3

- unit: m³ instead of kg dried matter content
- moisture and its influence on density and heating value considered
- multi output processes (economic allocation except for resource)
- CO₂ uptake as resource from air instead of negative emission
Moisture, density, upper and lower heating value

**density:** \[ \text{density}(x\%) = \text{density}(0\%) + \frac{\text{density}(0\%) \times x}{100} \]
densities of 450 kg/m³ for softwood and 650 kg/m³ for hardwood are taken as default.

**Theoretical lower heating value for complete incineration:**
\[ \text{lower\_heating\_value\_th}(x\%)[MJ/kg] = \text{upper\_heating\_value}[MJ/kg] - 1.32[\frac{MJ/kg}{100 + x}] \times x \]
→ the lower heating value depends (twice) on the moisture.

**upper heating value:**
independent on moisture: 20.4 MJ/kg for softwood and 19.6 MJ/kg for hardwood (per dried matter content)

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**allocation**

\[ AC_i = (V_i/V_{tot-AF}) \times V_{inp} \times \text{corr. bark} \]

- **Volume:** 11.3%
- **Allocation:** 5%
- **0.0715m³**

- **Volume:** 23.5%
- **Allocation:** 9%
- **0.16m³**

- **Volume:** 65.0%
- **Allocation:** 86%
- **-0.231m³**

residual wood, softwood, under bark, un=140%, at forest road
industrial wood, softwood, under bark, un=140%, at forest road
round wood, softwood, under bark, un=70% at forest road

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slide 9  presentation Hans-Jörg Althaus

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slide 10  presentation Hans-Jörg Althaus
selected results: plywood

Swiss Centre for Life Cycle Inventories

General Flow Information

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>Output</th>
<th>Allocation</th>
<th>Volume (m³)</th>
<th>Remarks</th>
<th>Mean Value</th>
<th>Unit</th>
<th>Source</th>
<th>Type</th>
<th>Source Mean Value</th>
<th>Uncertainty</th>
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<td>1.32</td>
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<td>12.92 (3.02, 5.26)</td>
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<td>plywood, indoor use, production</td>
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<td>1.32</td>
<td>CHF</td>
<td>12.92 (3.02, 5.26)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Swiss Centre for Life Cycle Inventories

Presentation Hans-Jörg Althaus
selected results: plywood

- Formaldehyde
- wooden board manufacturing plant, organic bonded boards
- treatment, plywood production effluent, to wastewater treatment, class 3
- transport, freight, rail
- transport, lorry 32t
- diesel, burned in building machine
- urea formaldehyde resin, at plant
- melamine formaldehyde resin, at plant
- electricity, medium voltage, production UCTE, at grid
- wood chips, from industry, hardwood, burned in furnace 50kW
- wood chips, hardwood, from industry, um40%, at plant
- hardwood, allocation correction, 1
- round wood, hardwood, under bark, u=70%, at forest road

selected results: plywood

- plywood, indoor use, at plant: Ecoindicator 99, (H,A)
- 9200 m²a forest + 90 m²a forest road
- 1170 kg biogenic CO₂ in wood, 440 kg fossil CO₂ emitted
- 170 g formaldehyde (resin and direct) 2.9 kg NOₓ (energy) 1.0 kg SO₂ (energy)
- 530 g particles
selected results: conclusions

- transparency prerequisite for interpretation
- $\rightarrow$ unit processes
- comparison of different materials (e.g. wood / mineral building materials) cannot be made based on single score indicators.
  $\rightarrow$ inventories are necessary for comparing results
Comparison of a Steel- with a Wooden Hall

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0  Content

1  Geometry
2  Materialization of a steel hall
3  Materialization of a wooden hall
4  Comparison of the masses
5  Comparison of the assessment results
1 Geometry of the hall

Basis for the materialization is a fictive building with following dimensions:

2 Materialization of steel hall

<table>
<thead>
<tr>
<th>Materials</th>
<th>Source</th>
<th>amount [kg]</th>
<th>note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortar</td>
<td></td>
<td>3.15E+04</td>
<td></td>
</tr>
<tr>
<td>Steel pillars and beams</td>
<td></td>
<td>4.50E+04</td>
<td></td>
</tr>
<tr>
<td>Reinforced concrete pillars and beams, steel part</td>
<td></td>
<td>3.00E+02</td>
<td></td>
</tr>
<tr>
<td>Reinforced concrete pillars and beams, concrete part</td>
<td></td>
<td>1.02E+04</td>
<td></td>
</tr>
<tr>
<td>Fibre cement board</td>
<td></td>
<td>1.49E+05</td>
<td></td>
</tr>
<tr>
<td>Insulation glass wool</td>
<td></td>
<td>2.97E+04</td>
<td></td>
</tr>
<tr>
<td>Insulation mineral wool</td>
<td></td>
<td>2.97E+04</td>
<td></td>
</tr>
<tr>
<td>Insulation polystyrol</td>
<td></td>
<td>2.43E+04</td>
<td></td>
</tr>
<tr>
<td>Foundation</td>
<td></td>
<td>1.13E+06</td>
<td></td>
</tr>
<tr>
<td>Windows</td>
<td></td>
<td>2.03E+04</td>
<td></td>
</tr>
<tr>
<td>Aluminium window frame</td>
<td></td>
<td>1.35E+04</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td></td>
<td>9.60E+03</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td>1.47E+05</td>
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<tr>
<td>Electricity use</td>
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<td>2.36E+03</td>
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<td>Reinforced concrete to final disposal</td>
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<td>1.05E+04</td>
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<tr>
<td>Steel pillars and beams to recycling</td>
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<td>4.50E+04</td>
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<tr>
<td>Fibre cement shingle in landfill</td>
<td></td>
<td>1.49E+05</td>
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<tr>
<td>Brick in landfill</td>
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<td>1.61E+05</td>
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<tr>
<td>Mortar to final disposal</td>
<td></td>
<td>3.15E+04</td>
<td></td>
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<tr>
<td>Roof steel to recycling</td>
<td></td>
<td>9.60E+03</td>
<td></td>
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<tr>
<td>Reinforced concrete from foundation to disposal</td>
<td></td>
<td>1.13E+06</td>
<td></td>
</tr>
<tr>
<td>Glass in landfill</td>
<td></td>
<td>6.75E+03</td>
<td></td>
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<tr>
<td>Aluminium to recycling</td>
<td></td>
<td>4.50E+03</td>
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<tr>
<td>Polystyrol to municipal incineration</td>
<td></td>
<td>8.10E+03</td>
<td></td>
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<tr>
<td>Glass wool mat to final disposal</td>
<td></td>
<td>9.90E+03</td>
<td></td>
</tr>
<tr>
<td>Rock wool mat to final disposal</td>
<td></td>
<td>9.90E+03</td>
<td></td>
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<tr>
<td>Building, hall, steel construction</td>
<td></td>
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<tr>
<td>Masonry to disposal</td>
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<tr>
<td>Windows to disposal</td>
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<td></td>
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<tr>
<td>Insulation to disposal</td>
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</tr>
</tbody>
</table>

• Summary of the construction elements (are taken into account for the assessment)
• Service life is included in the masses
• Green indicated construction elements are identical for the wooden and the steel halls (not taken into account for the assessment)
3 Materialization of wooden hall

- Summarized of the construction elements (taken into account in the assessment)
- Service life is included in the masses
- Masses of wood are calculated with the corresponding humidity densities
- Green indicated construction elements are identical for the wooden and the steel halls (not taken into account in the assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting structure and covering (wooden part)</td>
<td>2.84E+04</td>
<td></td>
</tr>
<tr>
<td>Supporting structure and covering (steel part)</td>
<td>1.22E+05</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>7.33E+04</td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td>6.66E+04</td>
<td></td>
</tr>
<tr>
<td>Walls</td>
<td>8.96E+04</td>
<td></td>
</tr>
<tr>
<td>Windows</td>
<td>5.56E+04</td>
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</tr>
<tr>
<td>Insulation</td>
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<tr>
<td>Foundation</td>
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<tr>
<td>Transportation</td>
<td>1.48E+05</td>
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</tr>
<tr>
<td>Disposal</td>
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<td></td>
</tr>
<tr>
<td>Service life 50 years</td>
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</tr>
<tr>
<td>Service life 20 years</td>
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<tr>
<td>Particle board</td>
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<tr>
<td>Steel parts</td>
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<tr>
<td>Roof steel</td>
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<td>Polystyrol</td>
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<td>Glass wool mat</td>
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</tr>
<tr>
<td>Rock wool mat</td>
<td>9.90E+03</td>
<td></td>
</tr>
</tbody>
</table>

4 Comparison of the masses

- Material weight for hall (1'500m²)

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<td>Glass</td>
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<td>Aluminium</td>
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<td>Rock wool mat</td>
<td>9.90E+03</td>
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</table>

Presentation: Daniel Kellenberger
5 Comparison of the assessment results

![Comparison of assessment results](image)

- **IPPC, GWP 100a (kg CO2-Eq.):**
- **eco-indicator 99, (H,A) (Dezi-points):**
- **ecological scarcity 1997 (Kilopoints):**