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Building Materials

A joint initiative of the ETH domain and Swiss Federal Offices

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Special LCA forum, December 5, 2003
EPFL Lausanne / session „building materials"

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Introduction

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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

contributors

- responsible institute: EMPA, Dübendorf
- project leader: Hans-Jörg Althaus
- authors: Daniel Kellenberger, Hans-Jörg Althaus, Frank Werner, Tina Künniger, 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

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EPFL Lausanne / Session „construction materials"

Mineral Building Materials

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0 Content

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

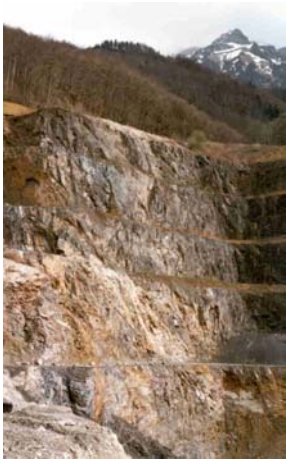
- Scientific Reports: often aggregated data, with another focus (e.g. emissions) or relation to process not clear
- Environmental Reports: often only representation of emissions which must be recorded by law and data which are economically relevant
- Management ratio: only economically relevant data
- 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

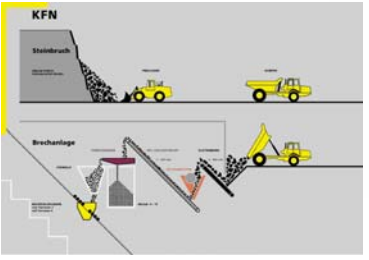
1. **Modelling of the production process**
2. **Analysis of the sub-processes (e.g. mining of limestone)**
3. **Drawing up a flow chart of the sub-processes**
4. **Study and illustration of the information**
5. **Cumulated energy demand and assessment results**

Mining of Limestone



Quarry of limestone factory KFN (canton GL)

Mangement ratio of limestone factory KFN to be analyzed.



Schematic illustration of the mining process of KFN

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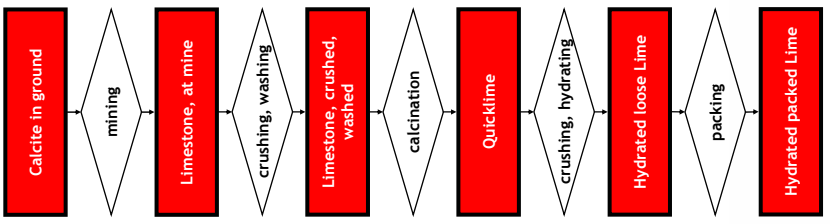
Production Process, main Products KFN



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Flow chart „mining of raw limestone"

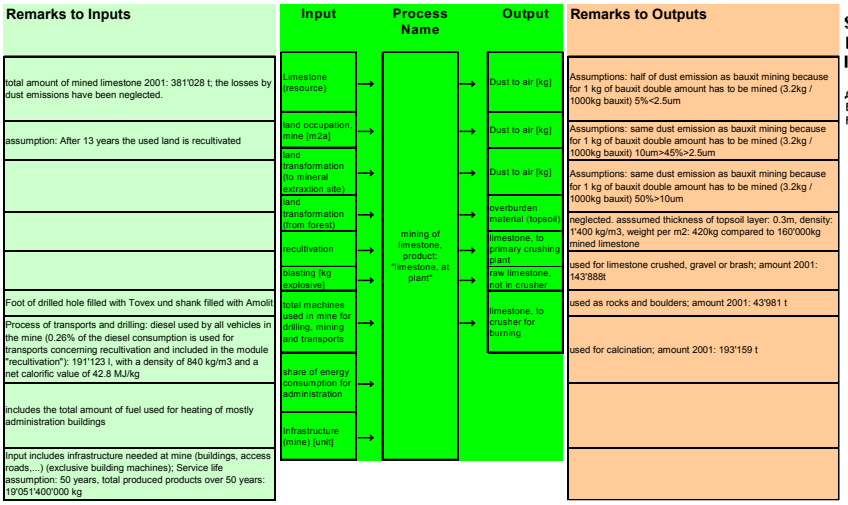

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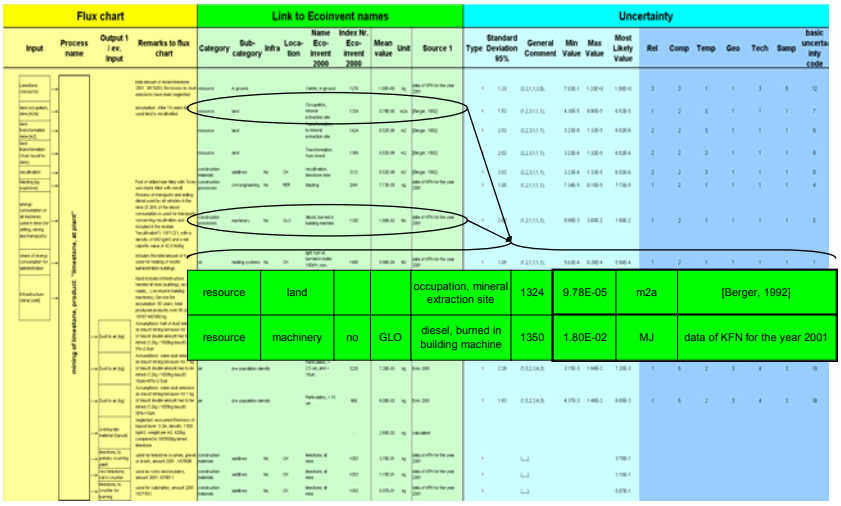
Illustration (Allocation and Quantity)



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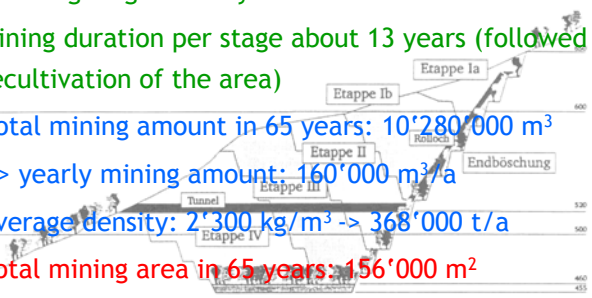
Land-use of limestone mining (KFN)

- 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 m^3
- -> yearly mining amount: 160‘000 m^3/a
- Average density: 2‘300 kg/m^3 -> 368‘000 t/a
- Total mining area in 65 years: 156‘000 m^2
- -> yearly mining area: 2‘400 m^2



- Land-use per kg product: 13a $* \frac{2'400 \ m^2/a}{368000000 \ kg/a}$ = 9.78E-05 m^2a

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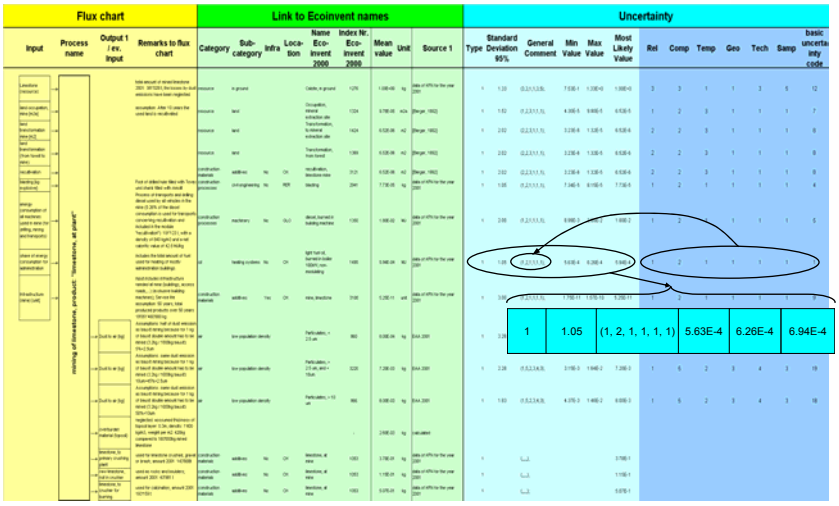
Illustration (Uncertainty)



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Uncertainty matrix (e.g. Heating Energy)

Indicator score	1	2	3	4
Reliability	Verified data based on measurements	Verified data partly based on assumptions OR non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. industrial expert); d… derived from theoretical … information (stoichi… enthalpy, etc.)
Completeness	Representative data from all sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50%) relevant for the market considered OR >50% of sites but from shorter periods	Representative data… only one site relev… the market conside… some sites but fro… shorter periods
Temporal correlation	Less than 3 years of difference to our reference year (2000)	Less than 6 years of difference to our reference year (2000)	Less than 10 years of difference to our reference year (2000)	Less than 15 years … difference to our re… year (2000)
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from smaller area than area under study, or from similar area	
Further technological correlation	Data from enterprises, processes and materials under study (i.e. identical technology)		Data on related processes or materials but same technology, OR Data from processes and materials under study but from different technology	Data on related pro… or materials but dif… technology, OR dat… laboratory scale processes and sam… technology
Sample size	>100, continuous measurement, balance of … based products	>20	> 10, aggregated figure in env. report	>=3

Reliability:
Verified data based on measurements

Completeness:
Representative data from > 50% of the sites relevant for the market considered over an adequate period to even out normal fluctuations

Temporal correlation:
Less than 3 years of difference to our reference year (2000)

Geographical correlation:
Data apply to the area under study

Further technological correlation:
Data apply to the enterprises, processes and materials under study

Sample size:
Continuous measurement

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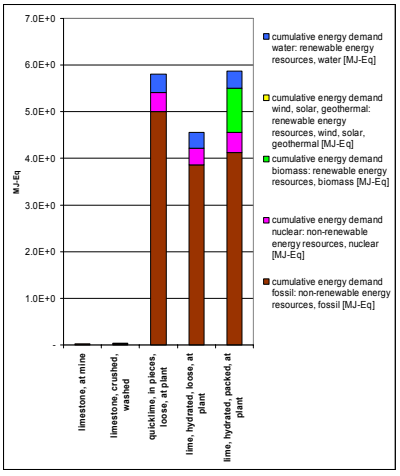
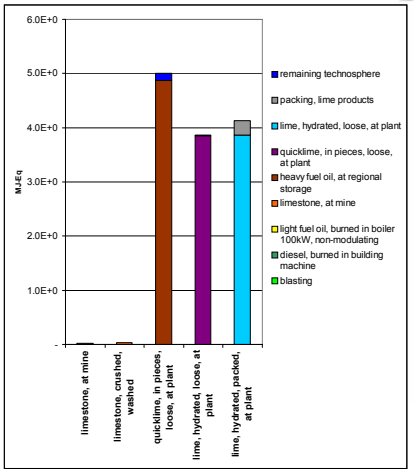
Cumulated Energy Demand



CED of different (intermediate) products with their energy production type



Fossil energy demand of different (intermediate) products with its relevant contributors

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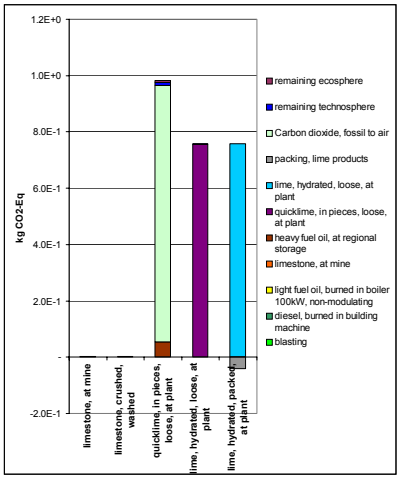
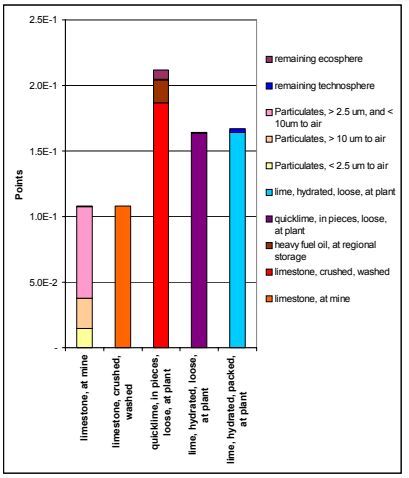
Results: GWP und EI 99 (H,A)



Global worming potential (IPCC 2001, GWP 100a)



eco-indicator 99 (H,A), total

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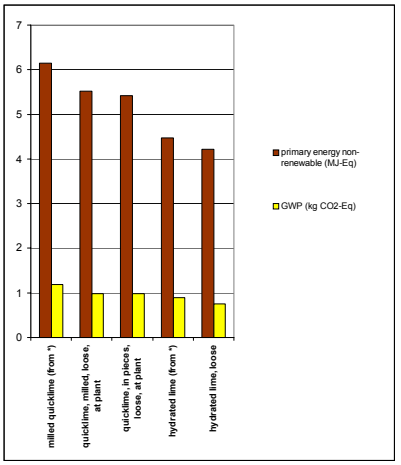
Comparison with other source



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

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5 Problems/Discussion

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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

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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.

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Wooden Materials

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content

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

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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

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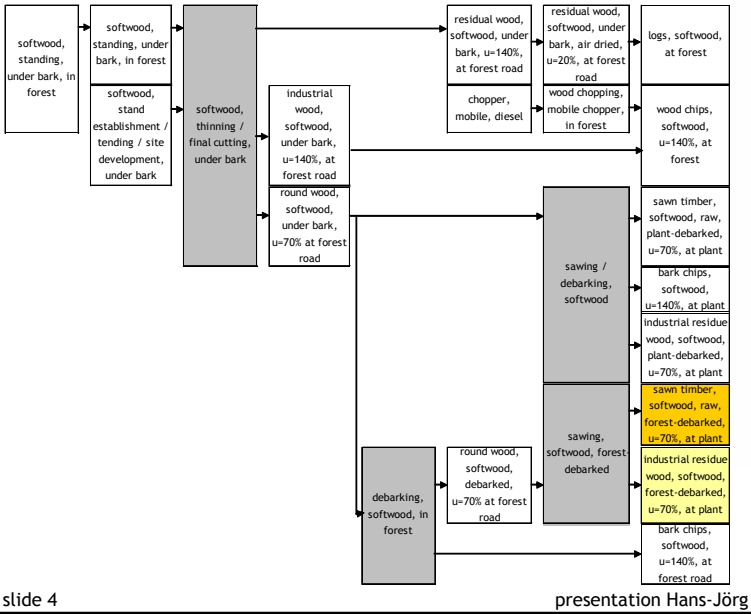
wood chain in ecoinvent



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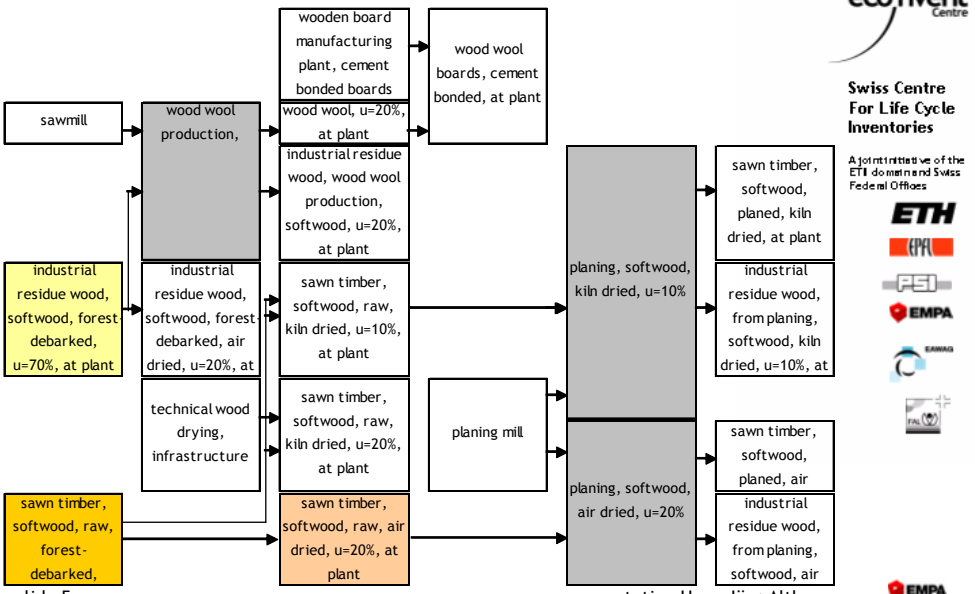
wood chain in ecoinvent



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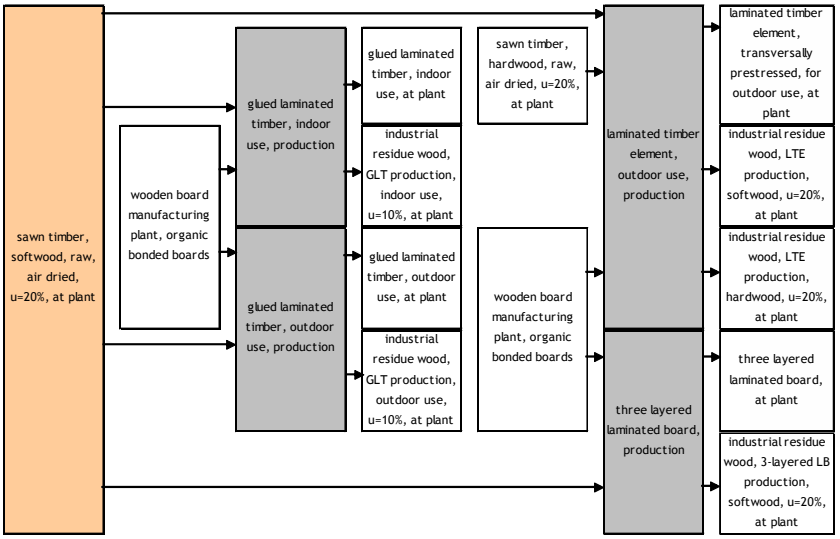
presentation Hans-Jörg Althaus

wood chain in ecoinvent



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presentation Hans-Jörg Althaus

data sources

- **forestry processes**: Schweinle 2001, Frühwald et al. 1996, Werner 2002, BFS/BUWAL 2000, Frischknecht et al. 1996, Bergmair 1996
- **sawing planing**: Ressel 1986, Hurst 1996, Frühwald et al. 1996
- **wooden boards**: Frühwald et al. 2000, Werner 1997, Frühwald et al. 1996, Wegener et al. 1994, Schniewind 1989, Ressel 1986, diverse Betriebe (pers. Mitteilungen), Nimz 1997
- **chips**: BFS/BUWAL 2000, Frischknecht et al. 1996
- **chemical protection**: Künniger et al. 2000, Hillier 1997
- **infrastructure**: expert guess

main differences to ÖvE3

- unit: m^3 instead of kg dried matter content
- moisture and its influence on density and heating value considered
- multi output processes (economic allocation except for resource)
- CO_2 uptake as resource from air instead of negative emission

Moisture, density, upper and lower heating value

density: $density(x\%) = density(0\%) + \frac{density(0\%) * x}{100}$

densities of 450 kg/m3 for softwood und 650 kg/m3 for hardwood are taken as default.

Theoretical lower heating value for complete incineration:

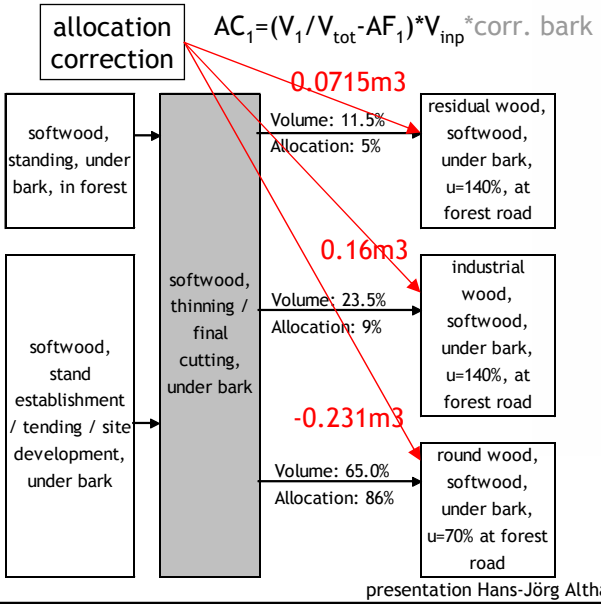
$$lower\_heating\_value\_th(x\%)[MJ/kg] = upper\_heating\_value[MJ/kg] - 1.32[MJ/kg] - \frac{20[MJ/kg] * x}{100 + x}$$

→ 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)

allocation



selected results: plywood

General Flow information									Uncertainty information		
Input	Process Name	Output	Allocation	source allocation	Remarks	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Roundwood beech, at forest road (u=70%)	plywood, indoor use, production				volume including bark is 2.7*1.12 m3	2.70E+00	m3	Plant data Hess & Co. AG Döttingen	1	1.12	(1,4,2,3,1,13)
Urea-formaldehyde resin incl. hardener, at plant						8.32E+01	kg	Plant data Hess & Co. AG Döttingen	1	1.12	(1,4,2,3,1,13)
Wood chips beech burned in 50kW furnace					Since the fuel for the furnace is included in the input, the corresponding amount inventoried with the energy module is subtracted. Since the volume of the chips is bulked, it is higher then the difference of input and output volume.	8.11E+03	MJ	Plant data Hess & Co. AG Döttingen	1	1.12	(1,4,2,3,1,11)
Chips						-1.92E+00	m3	calculated	1	1.00	calculated
Diesel burned in building machine						3.20E+00	MJ	Plant data Hess & Co. AG Döttingen	1	2.01	(1,4,2,3,1,15)
Electricity						3.06E+02	kWh	Plant data Hess & Co. AG Döttingen	1	1.12	(1,4,2,3,1,12)
Transport lorry					Chemicals: 100 km, wood: 50 km	1.57E+02	tkm	estimated	1	2.09	(4,5,nA,nA,nA, nA,5)
Transport rail					Chemicals: 600 km, wood: 100 km	3.48E+02	tkm	estimated	1	2.09	(4,5,nA,nA,nA, nA,5)
Process and cooling water						1.84E+00	m3	Plant data Hess & Co. AG Döttingen	1	1.12	(1,4,2,3,1,14)
plant						3.33E-08	unit	estimated	1	3.36	(4,5,2,3,4,5,9)
Hardwood, allocation correction			100%to plywood		adds / subtracts the amount of CO2 uptake, ressouce consumption and embodied energy	-1.32E+00	m3	calculated	1	1.00	calculated correction term
Hardwood, allocation correction		Outputs	100%to industrial residual wood		that is lacking / too much according to economic allocation. Also adds the 12% bark	1.32E+00	m3	calculated	1	1.00	calculated correction term

outdoor use:

melamine instead of urea-formaldehyde resin

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General Flow information									Uncertainty information		
Input	Process Name	Output	Allocation	source allocation	Remarks	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Inputs	plywood, indoor use, production	Plywood, indoor use, at plant	industrial wood as result of veneer production (veneer beech around 7'000 CHF/m3 to 10'000 CHF/m3; allocation fact. 1	estimation based on price list from Hefti & Grob, Niederhasli		1.00E+00	m3				
		Industrial residual wood beech, at plywood-plant I (u=20%)	60 CHF/Stere; 84 CHF/m3 u.b.; alloc. factor: 0	estimation after Werner 2002, based on Gautschi 2001 (value increased by 1.61 based on wood with u=140%due to lower water content (after Vhe Nr. 407 (2002))		1.32E+00	m3	calculated by balance of dry wood mass			
		Waste heat into air				1.10E+03	MJ	calculated	1	1.12	(1,4,2,3,1,1,13)
		Formaldehyde into air				8.32E-02	kg	Nimz 1997	1	2.81	(4,5,2,5,5,5,23)
		Wastewater				1.84E+00	m3	Plant data Hess & Co. AG Döttingen	1	1.52	(1,4,2,3,1,1,32)

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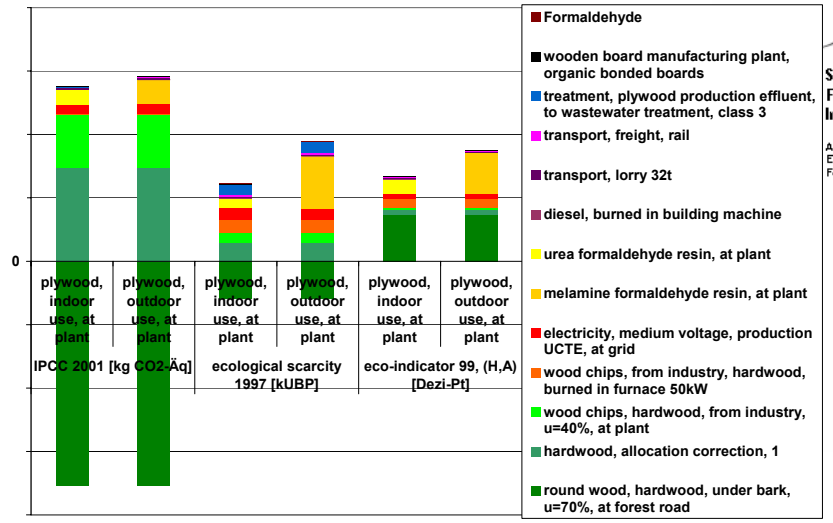
selected results: plywood



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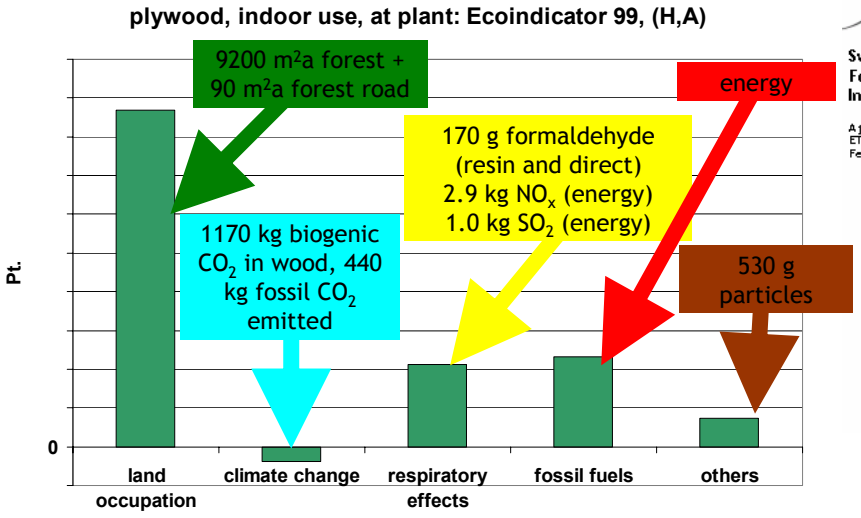
selected results: plywood



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selected results: conclusions

- transparency prerequisite for interpretation
- → **unit processes**
- comparison of different materials (e.g. wood / mineral building materials) cannot be made based on single score indicators.
  → **inventories are necessary for comparing results**

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Comparison of a Steel- with a Wooden Hall

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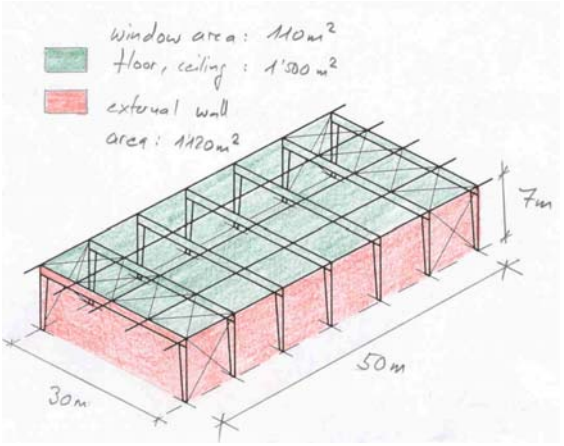
0 Content

1 Geometry of the hall

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



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2 Materialization of steel hall

	Materials	Group		amount [kg]	sum
Input	wall, masonry	Masonry		1.61E+05	3.96E+05
	mortar			3.15E+04	
	steel pillars and beams	Supporting structure and covering steel parts and reinforced concrete)		4.50E+04	
	reinforced concrete pillars and beams, steel part			3.00E+02	
	reinforced concrete pillars and beams, concrete part			1.02E+04	
	facing, fiber cement board			1.49E+05	
	insulation glass wool	Insulation		2.97E+04	
	insulation mineral wool			2.97E+04	
	insulation polystyrol			2.43E+04	
	foundation, concrete	Foundation		1.13E+06	
	window , double glazing	Windows		2.03E+04	
	aluminum window frame			1.35E+04	
	roof, steel sheet	Roof		9.60E+03	
	roof, rolling steel sheet			9.60E+03	
	roof, steel sheet, zink coating			1.60E+04	
	Transportation of all materials from factory gate to building ground	Transportation		1.47E+05	1.47E+05
	construction, maintenance and demolition with building machines	Energy		5.34E+04	5.58E+04
	electricity use for construction, maintenance and demolition			2.36E+03	
Output	reinforced concrete to final disposal	Supporting structure and covering to disposal and recycling		1.05E+04	3.96E+05
	steel pillars and beams and roof steel to recycling			4.50E+04	
	fibre cement shingle in landfill			1.49E+05	
	brick in landfill	Masonry to disposal		1.61E+05	
	mortar to final disposal			3.15E+04	
	roof steel to recycling	Roof		9.60E+03	
	reinforced concrete from foundation to final disposal	Foundation to disposal		1.13E+06	
	glass in landfill	Window to disposal		6.75E+03	
	aluminum to recycling			4.50E+03	
	polystyrol to municipal incineration	Insulation to disposal		8.10E+03	
	glass wool mat to final disposal			9.90E+03	
	rock wool mat to final disposal			9.90E+03	
	building, hall, steel construction				

- 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

Input	primary beams, glued laminated timber beams	Supporting structure and covering (wooden parts)	2.22E+04	3.39E+05
	secondary beams, glued laminated timber beams		3.33E+04	
	tertiary beams, structural timber beams		4.32E+04	
	wall: framework construction		2.16E+04	
	wall: facing (outside)		1.46E+05	
	wall: facing (inside)		6.66E+04	
	wooden pillars		6.48E+03	
	steel parts	Steel parts (nails, angles, etc.)	1.50E+04	1.50E+04
	rolling of steel parts		1.50E+04	
	steel parts, zink coating		8.96E+03	
	insulation glass wool	Insulation	2.97E+04	
	insulation mineral wool		2.97E+04	
	insulation polystyrol		2.43E+04	
	foundation, concrete	Foundation	1.13E+06	
	window , double glazing	Window	2.03E+04	
	aluminium window frame		1.35E+04	
	roof, steel sheet	Roof	9.60E+03	
	roof, rolling of steel sheet		9.60E+03	
	roof, steel sheet, zink coating		1.60E+04	
	Transportation from factory gate to building ground	Transportation	1.48E+05	1.48E+05
	construction, maintenance and deconstruction with building machine	Energy	5.34E+04	5.58E+04
	electricity use for construction, maintenance and deconstruction		2.36E+03	
Output	glued laminated timber to final disposal	Wood to disposal	5.55E+04	3.39E+05
	structural timber to final disposal (service life 50 years)		7.13E+04	
	structural timber to final disposal (service life 20 years)		1.46E+05	
	particle board to final disposal		6.66E+04	
	steel parts to sorting plant	reusage of steel parts	3.00E+04	3.00E+04
	roof steel to sorting plant	reusage of roof	9.60E+03	
	reinforced concrete to final disposal	Foundation to disposal	1.13E+06	
	glass in landfill	Window to disposal	6.75E+03	
	aluminium to recycling		4.50E+03	
	polystyrol to municipal incineration	Insulation	8.10E+03	
	glass wool mat to final disposal		9.90E+03	
	rock wool mat to final disposal		9.90E+03	
	building, hall, wood construction			

- Summary 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)

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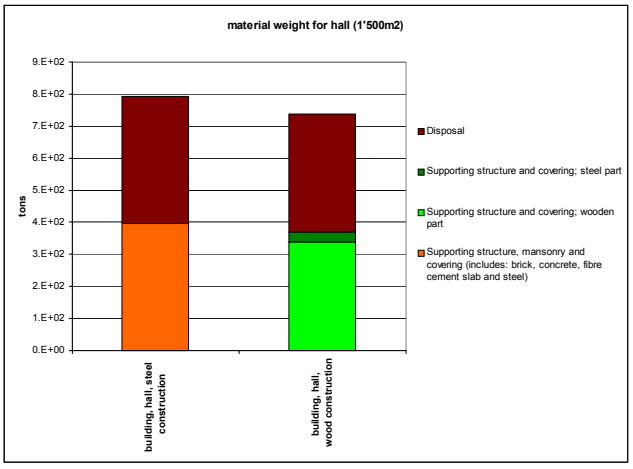
4 Comparison of the masses



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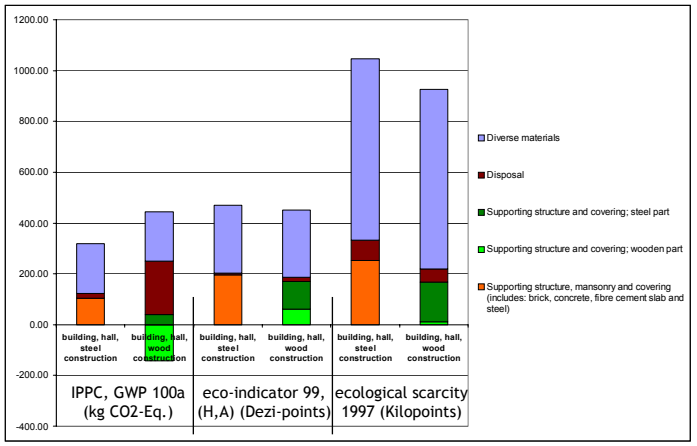
5 Comparison of the assessment results



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