LCA of climate friendly construction materials

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Introduction

In Switzerland, greenhouse gas emissions from the construction of buildings (erection and dismantling) have hardly decreased in recent years. This must change if the objectives of the Paris Climate Convention are to be achieved. The present study, financed by SwissEnergy and the City of Zurich, examined what may be expected from construction material manufacturers in this context. For that purpose, life cycle assessments of future production of construction materials relevant in structural engineering, namely mineral and metal materials, wood and plastics produced and/or used in Switzerland were performed. The report also covers life cycle inventory data of future transport services and energy supply.

Information about the technological development of manufacturing processes, transport services and energy supply were collected in interviews with representatives from associations and pioneering companies and with desk top research. Data and information collected were consolidated and complemented with assumptions where necessary and used to establish life cycle inventory datasets. The study refers to the time period between 2030 and 2050. The datasets were established according to the methodological approach of the Swiss platform "Life Cycle Assessment data in construction".

Main findings

With future construction materials manufacture, greenhouse gas emissions are reduced on average by 65 %, non-renewable primary energy demand by 48 % and the total environmental impact by 38 %.

At building level, greenhouse gas emissions of construction (including building technology) and dismantling can be reduced by 50-60 % - even though not all building materials used in the buildings examined have been modelled in terms of their potential future production. However, already with the current modelling, the greenhouse gas emissions are approximately equal to the SIA target value for the residential building Rautistrasse and 24 % below the SIA target value* for the office building ARE.

In terms of building operation, the Swiss energy transition, already anchored in law, will lead to a 55 % reduction in greenhouse gas emissions.

Detailed and quantified target paths towards a climate-friendly or even net zero greenhouse gas emission manufacturing were only available for a few of the industries considered. Most of the targets were of a more general nature and mainly involved a switch to renewable energy sources or an increase in the share of recycled feedstock material. Thus, the switch to renewable energy sources is also the measure considered in the future production of most of the building materials. An increase in energy efficiency is not expected for many materials, since according to the information received, this measure is fairly exhausted. Only the inclusion of carbon capture and storage (CCS) systems represents a major novelty compared to current production systems.

The results show that Negative Emission Technologies will be needed to reach net zero emissions by 2050.

* Target value of the swiss society of engineers and architects for energy-efficient construction

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More Information

Results

Data must not be used to compare the environmental impacts caused by the different construction materials because comparisons based on 1 kg of construction materials are misleading. Meaningful comparisons are possible only on the basis of the required quantities of the variants to be compared for a specific equivalent use.

Environmental impacts of 1 kg future building materials production [CED: kWh oil-eq.; GHGem: kg CO_2eq; overall env. impacts: UBP]

	lean concrete	building constr. Concrete	civil eng. Concrete	drilled piles concrete	precast concrete, high perf.	precast concrete, stand.	bricks	gypsum plaster board	float glass	aluminium	copper	nickel	steel	rolled steel	zinc	3-layered lam. board	glued lam. timber, outdoor	glued lam. timber, indoor	particleboard	fibreboard	glass wool	rock wool	linoleum	EPS	XPS	PE	PVC	PLA
GHG gas emissions	0.012	0.021	0.023	0.025	0.042	0.037	0.036	0.17	0.22	4.0	0.35	0.15	0.63	0.27	1.2	0.13	0.17	0.14	0.35	0.10	0.42	0.43	1.5	1.9	1.7	1.8	0.55	1.3
CED - non renewable	0.045	0.075	0.086	0.091	0.14	0.14	0.11	0.68	1.8	15	2.8	9.7	5.4	1.2	8.9	0.73	0.88	0.71	2.3	0.55	1.8	1.6	4.9	28	25	27	17	4.3
CED - renewable	0.052	0.073	0.078	0.082	0.16	0.20	0.24	0.16	1.1	20	2.8	14	3.4	1.2	7.7	9.5	8.8	8.8	3.1	8.2	3.5	0.76	13	1.1	1.3	1.6	0.57	9.3
Overall env. impacts	18	30	33	35	64	63	56	220	520	6700	1600	11000	2200	610	11000	940	710	680	470	380	980	550	24000	2300	2000	3400	2200	3900

Improvements achieved with future building materials production

	lean concrete	building constr. Concrete	civil eng. Concrete	drilled piles concrete	precast concrete, high perf.	precast concrete, stand.	bricks	gypsum plaster board	float glass	aluminium	copper	nickel	steel	rolled steel	zinc	3-layered lam. board	glued lam. timber, outdoor	glued lam. timber, indoor	particleboard	fibreboard	glass wool	rock wool	linoleum	EPS	XPS	PE	PVC	PLA
GHG gas emissions	-76%	-77%	-76%	-77%	-84%	-77%	-85%	-27%	-80%	-56%	-89%	-98%	-62%	-63%	-61%	-65%	-50%	-55%	-27%	-76%	-41%	-59%	-41%	-55%	-85%	-60%	-73%	-56%
CED - non renewable	-48%	-45%	-44%	-44%	-79%	-67%	-84%	-33%	-55%	-65%	-78%	-72%	-11%	-64%	-32%	-73%	-60%	-64%	-17%	-81%	-47%	-60%	-54%	-3%	-8%	-2%	1%	-68%
CED - renewable	575%	508%	492%	475%	181%	129%	213%	153%	760%	113%	-19%	87%	2145%	400%	245%	27%	17%	17%	-28%	25%	35%	136%	54%	218%	175%	109%	119%	24%
Overall env. impacts	-53%	-55%	-54%	-55%	-86%	-71%	-68%	3%	-54%	-40%	-92%	-36%	-15%	-37%	-65%	-22%	-21%	-21%	-21%	-39%	-17%	-44%	21%	-33%	-77%	-27%	-22%	-22%

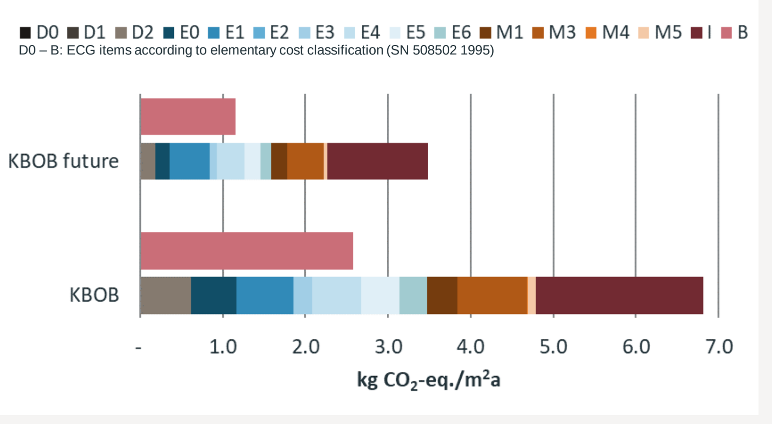
Building case studies

The LCI data established in this project were applied on two building case studies: the office building of the Swiss Federal Office for Spacial Development (ARE) in Ittigen, Bern and the residential building Rautistrasse in Zurich were assessed according to SIA 2040* to evaluate the effects of the changes in construction material production on the environmental impacts of buildings.

The functional unit and reference flow used in the buildings assessments is 1 m^2 energy reference area and year. The whole life cycle comprising construction, use and disposal is taken into account.

* Target value of the swiss society of engineers and architects for energy-efficient construction

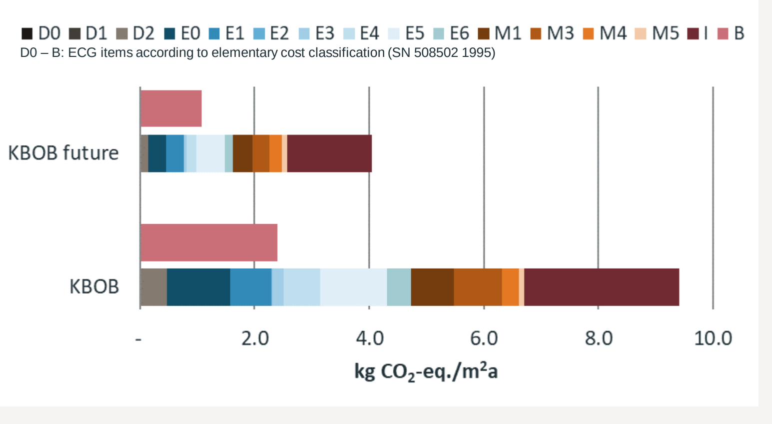
Office building ARE, Ittigen



Description
The office building ARE has 96 workplaces, is certified according to Minergie-P-ECO and constructed in a 2000-Watt-society compatible manner. It is a modern timber construction with the minimum of necessary concrete and has a very compact structure with reduced facade surface.

Results
The greenhouse gas emissions (figure above) of building construction and dismantling could be reduced by 49%, the non-renewable primary energy demand by 39% and the total environmental impact by 36%.

Residential building Rautistrasse, Zurich



Description
The residential building Rautistrasse has 104 apartments and has been built according to the Minergie-Eco standard. All apartments have comfort ventilation and are equipped with underfloor heating, which is supplied with heat from geothermal probes and electric heat pumps.

Results
The greenhouse gas emissions (figure above) of building construction and dismantling could be reduced by 57%, the non-renewable primary energy demand by 38% and the total environmental impact by 32%.

Methods and outlook

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Methods

The functional unit and reference flow used in the life cycle inventories of construction materials is 1 kg at the factory gate. The product systems encompass the extraction of the raw materials, their processing to construction materials, and their disposal. The use phase of the construction materials is excluded.

The following construction materials were analysed: cement (clinker) and concrete; bricks; gypsum plaster boards; float glass; aluminium; copper; nickel; steel; zinc; wood materials (three layered laminated board, glue laminated timber, particle board and soft board); glass wool; rock wool; linoleum; and plastic materials (PE, PVC, EPS- and XPS-insulation as well as PLA).

The environmental performance indicators assessed are: Cumulative energy demand (non-renewable and renewable); greenhouse gas emissions; and overall environmental impact.

The life cycle inventories described in this report are meant to be used in future oriented environmental assessments of buildings. They shall not be used to compare the environmental impacts caused by the different construction materials because comparisons based on 1 kg of construction materials are misleading.

The analysis refers exclusively to the primary production of building materials and current material losses in construction and manufacturing of building elements (except for structural steel supplied to the Swiss market). Further aspects of sustainable construction such as increasing the proportion of recycled feedstock materials, increasing the material efficiency or the lifetime of the buildings, optimisation of the building design, use of low-impact building materials and completely different construction methods, re-use of entire building components (circular economy approaches), were not considered.

Limitations

The present analysis refers exclusively to the primary production of building materials and current material losses in construction and manufacturing of building elements. The environmental impact of building materials may also be reduced by increasing the proportion of recycled feedstock materials or increasing the material efficiency. The study focused on the environmental dimension of sustainability.

If we look at the construction of entire buildings, there are even more possibilities to reduce the environmental and greenhouse gas footprints: optimisation of the building design, use of low-impact building materials and completely different construction methods (e.g. wood construction, clay, straw bales, alternative insulation materials) or re-use of entire building components. The reuse of building components can substantially reduce greenhouse gas emissions and embodied energy. The topic of circular economy should also be mentioned, as the reuse or recycling of building materials can be facilitated by appropriately designed building elements.

Outlook

The development of reduction paths is in full progress in many construction material industries. It can be expected that more concrete and comprehensive figures will be available in a few years. This would allow the results shown here to be made more accurate. It can be expected that the inclusion of alternative building materials or construction methods will make even more comprehensive greenhouse gas reductions possible.

Yet even with today's expected changes in production processes, substantial greenhouse gas reductions are within reach. However, this is not sufficient. Construction material industries need to reduce their greenhouse gas emissions (including supply chain) to close to zero. Such emission reductions require binding commitments to the 1.5° C target and substantial changes in the production processes.

The availability of alternative energy sources, especially biogas and biofuels, needs to be clarified in more detail. It is likely that the domestic potential would not be able to cover the demand of Swiss construction material industries and the road transport sector. There are also open questions regarding the feasibility and cost-effectiveness of CCS systems. Since such changes in production processes often involve major investments, clear signals from the Swiss Federal Council and a reliable legal framework issued by the Swiss Federal Parliament and the Cantons are needed.