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COLLECTION AND USE OF ENVIRONMENTAL DATA ON BUILDING MATERIALS

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Abstract
Environmental assessment of building elements and buildings requires environmental data related to the entire life cycle of the materials, inventory tools and assessment models for environmental impacts important to buildings. For that reason environmental data have been collected for a number of building materials in a project linked to a major Danish project on Environmental Management in Building Design. On the basis of this project the paper focuses on choice of important environmental parameters, on choice of system boundaries and allocation rules, on data quality, and on environmental assessment of building elements. The environmental data are accepted by a number of relevant manufacturers and trade associations.

1. INTRODUCTION

Environmental assessment of buildings includes life cycle assessment of the building elements and materials involved. Collection and use of environmental data for building materials have therefore been an essential subproject, see [1], linked to a major Danish project introducing environmental management of the design process to architects and engineers. The objective of the subproject has been to publish environmental data for building materials, which can be used during the design of buildings. The demands, which are commented upon in the paper, were to include:

- most categories of building materials,
- main processes for the materials in their entire life cycle,
- data regarding all essential impacts related to these processes, and
- reliable data accepted by manufacturers of the materials.

Besides, the data have been used to make environmental assessments of a number of building elements using a Danish model for impact assessment.

The materials were selected based on a screening of available data on the consumption of materials in the Danish building sector and on the energy used for production of the materials, and based on a rough estimate of the extent to which problematic substances are linked to the materials. Table 1 shows approximate figures on the annual consumption of the selected materials, and information from the project on the use of energy for production of the materials and on problematic substances linked to the materials.

First of all the selected materials represent energy consuming construction materials. Glass, paints, sealants, glue and a number of other materials are not considered in this project.

Materials	Amount	Energy	Total energy	Problematic substances
	1000 t	GJ/t	1000 GJ	
Gravel	**1400**	0,03	**40**	
Concrete	**7200**		**7000**	Grinding aids
In situ	4000	0,6	2400	
Pipes	1800	0,9	1600	
Elements	1100	1,7	1900	
Aerated, elements	300	3,6	1100	
Gypsum board system	**100**	6,0	**600**	Sealants
Masonry	**1150**		**2800**	
Fired clay bricks	700	3,5	2450	
Mortar	450	0,8	350	
Metals	**150**		**6300**	
Steel bars	120	17	2050	
Aluminium plates	20	190	3800	Chromic substances
Copper plates	0,5	76	40	
Copper pipes	1,2	81	100	
Zinc plates	7	48	340	
Wood (per m^3)	**450**		**5100**	
Softwood	400	11	4400	
Impregnated wood	50	14	700	Impregnation agents
Mineral fibres	**65**		**1350**	Chemicals in binders
Rock wool	40	14	550	
Glass wool	25	31	800	
Plastics	**30**		**2700**	Plasticizers, stabilizers,
PVC pipes	15	73	1100	monomers.
PVC floorings	3	96	290	
HPDE pipes	4	89	360	
LDPE foils	10	97	970	

Table 1. Amount of building materials used per year in Denmark, amount of energy needed to produce the materials and the problematic substances involved [1].

2. ENVIRONMENTAL PARAMETERS

The environmental assessment of materials includes three categories of impacts: Resource depletion, human health impacts and ecological health impacts. In the project a limited number of essential environmental parameters closely related to the environmental impacts has been chosen, see table 2.

Regarding *depletion of resources* data on *total energy consumption, feedstock energy,* and *fuels* have been collected. For recent low-energy houses the energy used to produce the building can account for up to 30 % of the energy used for heating the building, when the service life is estimated to 50 years [3]. Data are also given on the consumption of *scarce materials*, eg copper and zinc, and of *waste materials* and *water*. Various waste materials are reused in the building sector and especially in the construction sector. The *consumption of water* in the building industry is very low.

Impact categories	Environmental impacts	Environmental parameters
Resource depletion	Scarce energy sources	• Oil, natural gas
	Scarce materials	• Cu and Zn
	Scarce water resources	• Water
	Landscape	Not included
Human health	Working environment	• General information
	Indoor climate	• General information
	Human toxicity	• SO_2, NO_x, CO, VOC and NMVOC • Pb, Cd and Hg to air • Other emissions to air • Dangerous substances to water
Ecological health	Global warming	• CO_2 and CO
	Ozone depletion	Not included
	Photochemical ozone formation	• VOC, NMVOC and NO_x
	Acidification	• SO_2 and NO_x
	Eutrophication	• Water consumption • COD, N- and P- containing substances
	Ecotoxicity	• Pb, Cd and Hg to air • Other dangerous substances to air • Dangerous substances to water
	Persistent toxicity	• Non ready biodegradable substances
	Waste	• Categories of wastes
Problematic substances		• Problematic substances used in production and/or present in the product

Table 2. Environmental impacts and related environmental parameters used in the project, see also table 3.

The collection of data related to *human health impacts* has included emissions, which contribute to human toxicity, and general information considering impacts on *work environment* and *indoor climate.* This information comes from the trades and from the Danish indoor labelling scheme for building materials. Emissions such as *SO_2, NO_x, CO, VOC*, some *heavy metals,* and *dangerous substances* contribute to human toxicity, see table 2.

Ecological health impacts are the reason for the collection of data on energy-related emissions to air, such as *CO_2, SO_2, NO_x, CO, VOC* (volatile organic compounds) and *NMVOC* (non-methane volatile organic compounds) and *heavy metals*. For the aquatic environment *lead, cadmium, mercury, organic matters and nutrients* are used as indicators for substances causing pollution, when discharged into the aquatic environment.

Table 3. Environmental data for gypsum boards as presented in [1] and in the handbook on environmental management in building design.

Environmental data for gypsum used for walls (A/B/C): Data quality				PRODUCTION				USE	REMOVAL
				Raw materials extraction and production (1)	Manufacturing of building products	Construction	Total	Use and maintenance	Demolition and waste management
INPUT	Energy	Total energy	GJ/t	1,1	4,0	0,2	6		
		Feedstock energy	GJ/t						
		Coal	kg/t	(2)	(2) 19		22		
		Oil	kg/t		46	0,3	53		
		Natural gas	Nm^3/t		8		9		
	(A)	Waste gas	Nm^3/t		23		26		
	Materials	Scarce materials	t/t						
	(A)	Waste materials	t/t	waste paper 0,05	(4) Manu. gypsum 0,67		Fibres 0,06 Manu. gypsum 0,77		
	Water		m^3/t	■	■		■		
OUTPUT	Emissions to air (B)	CO_2	t/t	0,07	0,20		0,3		
		SO_2	kg/t	0,51	1,2		2,0		
		NO_x	kg/t	0,25	1,3		1,8		
		Pb	g/t	0,01	0,03		0,05		
		Cd	g/t	0,001	0,001		0,002		
	(C)	Hg	g/t	0,001	0,001		0,002		
		CO	g/t	39	150	58	280		
	(B)	NMVOC	g/t	1	32	32	70		
	Emissions (B) to waste water	Suspended solids	kg/t	< 0,025			< 0,03		
	Waste (3)	Material / loss	%			15 D	15 D		D
		Fibres	kg/t	2 B			2 B		
	(B)	Sludge	kg/t	1,3 D			1,5 D		
	Working environment			General information	General information	Gener. infor.			■
	Indoor climate							Indoor label.	
OTHER	Problematic substances	in the material		Specific information					
		in the processes							
	Service life		Years					20 - 60	
	Paticular processes			Product. kraft paper					

(1) Data given per ton gypsum . (2) Total consumption of energy sources. (3) B: burned; D: disposal. (4) Manufactured gypsum from degassification of coal flue gass·.s.

As far as waste is concerned, information is given for *solid waste suitable for disposal* as volume waste, slag and ash, dangerous waste or radioactive waste. The building and construction sector account for approximately 20% of Danish waste, out of which more than 80% is recycled.

Beside the data directly related to the environmental impacts, problematic substances are mentioned, when they are used in the production or incorporated in the product. The exposure of these substances is not assessed. Problematic substances are defined as substances mentioned in Commission and Council Directives (see note).

3. SYSTEM BOUNDARIES AND ALLOCATION RULES

Building materials are defined as they exist in the final building, and to specify the materials these are linked to specific building elements. Building materials do not include supplementary materials necessary for the completion of these building elements, eg concrete in elements does not include reinforcement.

For each material all stages in its life cycle are considered. Also processes related to supply of fuels and electricity are included, at least inputs and outputs related to consumption of energy. For electricity European average data are used for production of electricity.

Regarding waste management, data express current practice. For some materials scenarios on waste management are also mentioned. Roughly estimated intervals for *service life* are given for the building elements linked to the materials.

Processes within the scope of the project, for which essential data are not available, or for which the data given do not fully reflect the environmental impacts, are mentioned separately as *particular processes*, eg forestry and extraction of raw materials, see table 3.

Processes related to supply of water and production and transportation of equipment are considered not to be important.

Processes related to use and operation of the building are beyond the scope of the project. So are fire and other accidents. Waste management and waste water treatment are also beyond the scope of the project, but will be considered more closely in future projects.

The allocation rules used are simple. All inputs and outputs are allocated to main products and byproducts, not to reused materials or to waste materials. All inputs and outputs related to power plants are allocated to the production of electricity.

Note: Commission Directive (93/101/EEC adapted to 67/548/EEC) about regulations of dangerous substances, Council Directive about dangerous substances discharged into the aquatic environment (76/464/EEC) and Council Directive for hazardous waste (91/689/EEC).

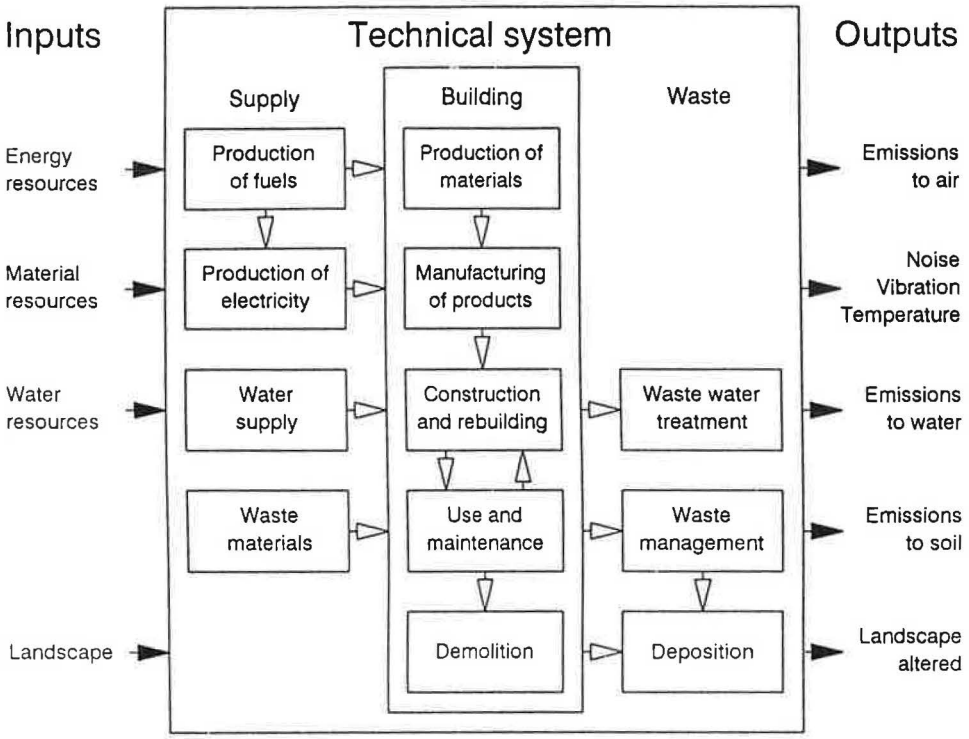

Figure 1. The life cycle for buildings and building materials and supplementary processes related to supply of electricity, fuels and water, and to waste and waste water management. Also a number of essential inputs and outputs are shown, and recycling is indicated.

4. DATA QUALITY

In the project the data quality has been assessed looking at reliability of data sources, representativeness of data, variation of data, age of the data, and at missing and deviant data.

Assessment of the *reliability of data* includes a description of, whether collected data are measured, calculated or estimated, and an assessment of the data sources for reported data. All the data used in the project have been collected from well-defined sources, and the processed data have been discussed in detail with and accepted by the manufacturers.

Representativeness of the data has included an assessment of the extent to which the collected data fulfil the purpose of the study, which has been to collect representative data on building materials used in Denmark. For materials produced in Denmark, such as concrete, gypsum boards and bricks, data have been collected by interviewing Danish manufacturers. For imported materials, such as metals and plastics, it is more difficult to obtain reliable and representative data, see table 4.

Products	Manufacturers in Denmark and their market share		Data sources and variation between various manufacturers	
Concrete	Several manufacturers	100 %	Interview, various manufacturers	25 %
Fired clay bricks	Several manufacturers	100 %	Interview, one manufacturer	40 %
Steel bars	One manufacturer	50 %	Interview, one manufacturer	25 %
Aluminum plates	Import Norway/Germany		LCA-reports, Germany/Norway	?
Mineral fibres	Four manufacturers	90 %	Report, EU eco-labelling	?

Table 4. Origin and market share of a selected number of materials. Data sources and data variation between various manufacturers are shown too.

Variation has included an estimate of the uncertainty of the data as well as of the variation between data from different plants. The variation is much greater than the uncertainty. For products made in Denmark it is possible to estimate this variation (20-40 %) and to explain it by differences in the technology level and/or different production methods. For imported products this is much more difficult. Because the variation is considerable, the variation between various manufacturers of the materials should be taken into account, when the data are used for environmental assessment of building elements.

Missing data are pointed out, see table 3. *Deviant data* are commented upon. The deviations can originate from differences in system boundaries and/or in allocation rules. The system boundaries, the allocation rules and the processing of the data are described in detail in the project together with the most important production processes for each material [1].

In table 3 the data quality is estimated as good, medium or bad (A/B/C) based upon defined criteria regarding the mentioned quality indicators.

Impacts		Impacts per m^2 per year	Normalisation values per person	Person equivalents 10^{-6}
Resources				
Oil	kg	0,11		4
Natural gas	Nm^3	0,020		0,9
Environmental impacts				
Global warming	kg CO_2 eqv.	1,2	8.700	140
Photochem. ozone format.	kg C_2H_4 eqv.	0,000067	20	3
Acidification	kg SO_2 eqv.	0,0056	124	42
Eutrophication	kg NO_3 eqv.	0,0059	298	20
Ecotoxicity				0
Persistent toxicity				10
Human toxicity				14
Waste				
Volume waste	kg	0,13	1.350	96
Slag and ash	kg	0,0068	350	20
Radioactive waste	kg	-	0,035	-
Dangerous waste	kg	0,0002	20,7	10

Table 5. Environmental profile for a reinforced concrete slab element using a Danish model for impact assessment. The resource consumption is divided by world reserves.

5. ENVIRONMENTAL PROFILE FOR A BUILDING ELEMENT

The environmental data for building materials have been used for environmental assessment of various building elements, eg for reinforced concrete slab elements as shown in table 5. The environmental data for the building materials involved have been aggregated using a database and an inventory tool [4]. A Danish impact assessment model [2] has been used to calculate the normalised potential impacts related to the building element. The assessment includes calculation of impact equivalents and normalisation, see table 5. The toxicity measures are specifically defined in [2].

The environmental profiles of building elements can be used to compare alternatives or to derive general environmental profiles for various building elements to be used as references.

6. CONCLUSIONS AND PROPOSALS

The project has shown, that it is possible to collect reliable environmental data for a number of building materials for essential processes during their entire life cycle. Valuable data are especially obtained on the energy consuming processes. Further information and data are needed on the environmental consequences of raw materials extraction and waste management.

Data of use for the assessment of impacts on resources and ecological health have been collected. Further data are first of all needed for the assessment of impacts on the working environment and indoor climate. Better information is also needed on the use of problematic substances, especially when data about materials such as paints and sealants are to be collected.

The collected data have been accepted by a number of Danish associations and manufacturers. In the future environmental data should be provided by the manufacturers, eg using environmental declarations and green accounts. Standardisation is needed to ensure the quality of environmental assessments based on environmental data from various sources, and data on the variation between data from different plants have to be obtained too.

Finally it has been shown that environmental data for materials can be used for environmental assessment of building elements and buildings intensifying the need for reliable environmental data for all essential building materials.

References

[1] Hansen, K., H. Krogh, L. Hoffmann et al. Environmental data for building materials (in Danish, English summary). Danish Environmental Protection Agency, Copenhagen, 1997.

[2] Wenzel, H., Hauschild, M. and L. Alting. Environmental Assessment of Products: Volume 1- Methodology, tools, techniques and case studies in product development. Chapman & Hall, United Kingdom. 1997.

[3] Krogh,H., K. Hansen and H.K. Knudsen. Environmental data for selected building materials (in Danish with summary in English). Consumption of fossil fuels and emissions of CO_2 and SO_2 SBI Bulletin 113. Danish Building Research Institute 1995

[4] Petersen, E. Database and inventory tools for building elements and buildings' environmental parameters (in Danish with summary in English). SBI report no. 275. Danish Building Research Institute.