ANNEX 31

Data Needs and Sources

Annex 31
Energy-Related Environmental Impact of Buildings

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CONTENTS

DATA NEEDS AND SOURCES

The data needed to assess the energy related environmental impacts of buildings depend strongly on the type of tool used and, among others, on the aggregation level considered (product/building/stock). The general categories of data required by each type of tool are described in the Annex 31 report **Types of Tools**. In this report a more detailed examination is conducted of data requirements and sources. An attempt is made to inventory as exhaustively as possible the data needed for a complete detailed assessment of impacts at any aggregation level.

Most LCA tools provide a database with generic inventory data, and some with building-oriented data. These data have to be checked for their quality and relevance to ensure that an appropriate fit is found between the data inputs and the case under study. Passive tools like checklists and guidelines tend to be more self-contained and no external data may be required other than building specifications. Checking has to be made to verify that the assumptions built into such tools are based on relevant data of sufficient quality.

Basic Data For Energy, Transport & Waste Disposal Processes

LCA tools need inventory data not directly related to the project under study, including data for energy, transport and disposal process chain throughout the life cycle of a building. Christine Hemming, from Chrysalis Environmental Consulting (UK) prepared for SPOLD [Spo 95] in November 1995 a "Directory of Life Cycle Inventory data sources". About 41 databases were reviewed. Among them, 28 were reported to include data about energy (fuels and electricity), transport and waste treatment. The availability of these data are summarised in Table 1. Several databases (marked in this table by a *) contain also building product data and as such are presented further in this chapter.

		1 Boustead (UK)	2 BUWAL (CH) *	3 DEAM (EU) *	4 DEAM (USA) *	5 EDIP (DK) *	6 Ecomanager	7 EcoPro (CH) *	8 EcoInvent (CH)	9 GaBi (D) *	10 Heraklit (D) *	11 INCPEN (UK)	12 ISWM (UK)	13 Italy	14 IVAM (NL) *	15 KCL (F)	16 LCA iT (S)	17 LiMS (USA)	18 Miljöbalans	19 NEP (S) *	20 Ökobase (CH) *	21 PEMS (UK)	22 PIA (NL)	23 Regis (CH) *	24 REPAQ	25 SimaPro 3.0	26 Temis 2.0 (D) *	27 TU Delft (NL)	28 Umberto (D) *
Fuels	Propane	X		X		X			X									X	p						X				
	Oil	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	p	X	X	X	X	X	X	X	X	X	X
	natural gas	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	p	X	X	X	X	X	X	X	X	X	X
	Coal	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	p	X	X	X	X	X	X	X	X	X	X
Electricity	from non renewable resources	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	p	X	X	X	X	X	X	X	X	p	X
	from renewable resources	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	p	X	X	X	X	X	X	X	X	p	
Transport	private car	X		X	X				X	p	X	X	X						p		X		X				X	X	X
	Road	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	p	X	X	X	X	X	X	X	X	X	X
	Rail	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	p	X	X	X	X	X	X	X	X	X	X
	river/sea	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	p	X	X	X	X		X	X	X	X	X
	Air	X			X	X	X								X				p		X		X	X			X	X	
Waste treatment	Recycling	X	X	X	X	X	X	X			X		X	X	X			X	X				X		X	X	p		
	Incineration	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X			X	X	X	X	X	p		X
	Landfill	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X				X		X	X	X	p		X

** = these databases contain also building product data and are described further in the present chapter*
p = possible (insufficient data available)

Table 1: Data availability in the data base reviewed by [SPOLD 95]

Building Data

Building data has been divided into 'static', and 'dynamic' data. Static data relates to the building intrinsic physical characteristics; dynamic data relate to occupancy behaviour, maintenance scenarios, and other time-dependant variables. Each category is elaborated below:

"Static" data:

Product level :

- functional, and physical characteristics of construction elements, products & materials (e.g. thermal conductivity or U-values, thermal mass, air & water tightness, etc.),
- location of resources, transport distances,
- nature and quantities (mass) of the product & materials involved into the construction of the building.

Building level :

- thermal efficiency of building envelope : global heat loss coefficients (K-values) of walls, glazing, floors, ceilings,
- air change rate,
- recovery efficiency of solar and occupational heat gains (absorptivity/emissivity of sunny walls, thermal inertia of indoor masses, regulation efficiency, efficiency of heat recovery of exhaust air)
- nature of energy used for space heating,
- thermal zoning,
- energy needs for other uses than space heating, e.g. warm water production, cooling, lightening, cooking, ...
- heat generation, distribution, regulation and emission efficiencies,
- DHW generation, storage and distribution efficiencies,
- other energy use efficiencies.

Stock level:

- energy (per type) & water use, waste water & solid waste generated, personal transports used per time unit per building type and/or per occupant,
- building stock description : # of buildings-e.g. or m^2 of floor area per building type

Dynamic data:

- occupancy profile (daily, weekly, yearly)
- assumption about tenants behaviour (DHW consumption profile and use scenarios for heating, lightning, window openings, etc.)
- maintenance & refurbishment scenarios
- replacement frequencies of building materials, products & elements

Building data sources

Building data are provided by the descriptive operational documents of a project. The tools used to assess impacts have to fit the level of details of the data available at each step of a project.

Site Specific Data

Climatic data

- degrees-days base 18°C, base 14°C, other bases
- mean external air temperature
- mean global solar radiation
- mean drink water temperature (for warm water production)
- mean wind speed and direction

- Periodicity of climatic data: yearly, monthly, weekly, hourly values (depending on the level of detail of the model used)

Infrastructures

- *Energy* : availability of energy sources : urban heating, natural gas, fuel oil, electricity grid, LPG, geothermics, wood, wind, solar, other renewable energy,
- *Water* : availability and quality of public water supply, of rainwater draining, of sewage pipes and waste water treatment plant,
- *Waste* : availability of public solid domestic waste collection, type of waste sorting, if any, fate of sorted waste (recycling, compost, incineration, landfilling)
- *Transport of persons* : accessibility of community transports (suburb, tramway, bus, train),
  availability of roads restricted to bicycles
- *Other services* : depending of the building category (function) : transport of goods, of information, supply of specific products or fluids, treatment of specific waste, etc.

Site specific data sources

Site data are often not available at the level of details needed to allow an accurate assessment of Energy Requirements and Environmental Impacts of Buildings (EREIB).

Climatic data

- Meteorological data, including degree-days are provided by national Meteorological Boards. In some countries, solar irradiation data are given by specific literature (e.g. Atlas Solaire Français). Hourly data needed by some detailed thermal models are computed from Meteorological Office data and sold by private consultants.
- Public supply water temperatures are needed to compute the energy needed for DHW. No general rule applies to identify the source of such data.

Infrastructure data

Source: local authorities

Environmental Data

Theoretically, the environmental data needed to assess the EREI of a building should include some initial state environmental assessment, including inventories of threatened vegetable and animal species, water and air quality, etc.

The air quality is classically divided into external and indoor air quality. Water quality should be divided into drinking water quality and quality of superficial and ground water concerned by liquid releases of the life cycle of buildings (sensitivity of the receiving media to pollutants).

In fact, although site-sensitive methods are expected to become available in the next few years, the existing methods used to assess impacts are not site-sensitive, since such methods are not yet available in the LCA field, nor in the building field, except for acoustic comfort assessment.

Therefore, none of these methods use site-specific environmental data, but generic data which are described below.

External environment

- <u>Life Cycle Inventory (LCI) data</u>
  Energy and environmental characteristics of construction elements, products and materials (LCI from cradle to gate or from cradle to grave) and infrastructures of the building.
- <u>Life Cycle Impact Assessment (LCIA) data</u>

The environmental impacts of in- and out-flows generated by the life cycle of a building are characterised by *characterisation factors*, which are given by Life Cycle Impact Assessment methods like CML (NL) or Critical volumes (CH) for several predefined impact categories. For CML, these are:

- global level: global warming, ozone depletion, ecotoxicity, human toxicity,
- regional level: acidification, nutrification, photochemical oxidant creation,
- local level: odour, noise.

A prioritisation of impact categories is available at a national level in some countries (e.g. Sweden, The Netherlands, etc.)

Other methods use safeguard subjects (EPS) or damage fields (Critical surface-time). The software tools including impact assessment methods are generally provided with their own sets of site-independent characterisation factors.

Indoor Air Quality (IAQ)

A satisfying IAQ level is generally considered to be reached by minimal air refreshment rate required for non smoking / smoking / cooking / other pollutant-specific area, sometimes by maximal concentrations of specific pollutants (e.g. formaldehydes, VOCs,). The latter case leads to select low-emissive building products and/or to increase the air change rate, which may increase the heating needs[1]. Data needed then are the emission rate of the building products. Unfortunately these data are not available since such emissions are decreasing over the time at a rate which strongly depends on the way the product is implemented into the building and ventilated. Theoretical calculations are possible but require dynamic data that are not yet available since not measured.

Comfort

Hygrothermal comfort, noise, visual comfort (lighting) are expressed by case specific quality level requirements. Few tools used to assess impacts consider these comfort parameters at the moment. Some thermal models compute summer maximal temperatures, while acoustic and lighting comfort are assessed by specific tools. The comfort-related data needed to assess impacts are:

- the physical & geometrical characteristics of the rooms under study,
- the technical characteristics of the devices storing, generating and transmitting heat, noise or light present in these rooms.

Drinking water quality

Physical and chemical characteristics of drinking water supplied by public grid and of the internal water supply network which can modify them.

Domestic hot water (DHW) quality

A relatively high temperature is needed in DHW tank storage to avoid Legionella development, which may lead to a high-energy consumption and reduces solar energy collection efficiency, if any. [2]

Environmental Data Sources

<u>External environment</u>

The data concerning external environment are method-specific (see above) and are given by the methods and tools providers.

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[1] We can see here an example of conflict between two impacts aspects (health protection and energy saving).

[2] This is another example of conflicting requirements between health protection and energy saving, for a device (a water tank storage) required to satisfy a certain quality level (comfort of use of DHW), given the choice of a certain energy carrier (electricity).

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Indoor air quality
Air change rates are given by national regulation or by the building programme. Emission of pollutants by building products will probably be given in the future by manufacturers.

Comfort
Comfort requirements are given either by national regulation or by the building programme. Comfort-related parameters are product-specific and as such are provided by the manufacturers.

Water quality
Data on water quality are generally provided by local administrative and health authorities.

DATA QUALITY

The quality of the data to be used to assess impacts has been quite well discussed for Life Cycle Inventory (LCI) data. This discussion is mostly translatable towards other types of data and deals mainly with the quality of LCI data.

The SPOLD format

The Society for the Promotion of LCA (SPOLD) has developed a common format for LCI data, to facilitate data exchange and improve quality [Spo96]. Besides the « classical » input/output flows, the format contains descriptive data (metadata) : subsystem structure, boundaries, quality, representativity, energy/transport/waste models, supporting the choice of relevant data sets.

The data quality indicators (DQI)

The commonly used data quality indicators [3] may be listed under the following categories:

- Accuracy
- Completeness
- Representivity
- Repeatability
- Variability

Accuracy

Statistical representivity

Are the data resulting of a single measurement or are they averaged over repeated measurements? Number of measurements? Frequency? Representiveness of the time period of measurement?

Age of data

How old are the data: at the flow level? at the process level?
(example of scale: < 5 yrs, between 5 and 10 yrs, > 10 yrs, unknown)

Acquisition method

Does the data result from a measurement? a theoretical calculation? an authorised guess ? Is the origin unknown? Has the data been validated? by an independent expert (critical review) ?

Completeness

Exhaustivity of the flows

Are significant flows (i.e. able to modify significantly the global impact assessment result) missing?

[3] This list comes from a collective study under publication made for a French association of 15 energy providers and product manufacturers.

Aggregation level of the flows

Have some flows been aggregated which have significantly different environmental impact?

If yes, may this aggregation have a significant impact of the global impact assessment result?

Mass balance at process level

This calculation may be very useful, when performed at the elementary processes level, to identify errors or missing flows.

Representativity

Geographical representativity

Is the geographical representativity of the process reported clearly stated (at a local, national, continental level)?

Time representativity

Is the age of the data adequate with the process under study?

Technological representativity

Is the process technology representative of today's mean occidental technology or is it known as obsolete?

Repeatability

A good LCA study should be transparent enough to lead any neutral expert to the same conclusion, providing the acceptance of the assumptions and of the assessment method used. Among these assumptions, the inventory data used play a crucial role. Their use must be unambiguous and coherent, in a way which is described by the three following criteria, which apply also recursively to the elementary process inventory data used as well, and therefore to the database itself:

Functional unit definition

Is the product or service characterisation explicit ? relevant ? sufficient ?

Inclusion rules at the system level

Which criteria are used to decide to include a flow into the system or not ? a mass criterion ? an energetic criterion ? the environmental relevance ?

Allocation rules

Are the allocation rules transparent ? justified ? relevant ?

Variability

Any data should be given with an indication of its variability : mini , maxi, standard deviation, etc. This information should permit perform sensitivity analysis, i.e. to test the robustness of a conclusion against the uncertainty of the data.

Synthesis

Many data quality indicators have been proposed in the literature, but as far as we know, none of them has been implemented yet in a database. The above-mentioned questions are a good state of art of a data quality assessment checklist, knowing that today most of these questions will remain unanswered, because of a generalised lack of « metadata ».

According to [Spi95], the « metadata », concerning numeric data, comprises information such as age, means of acquisition, literature references, geographic and other representativity, etc., i.e. all the information which permits assessment of the data quality.

Unfortunately, very few existing databases give enough metadata to perform a correct data quality assessment.

Survey of Existing Data Bases

Introduction

As part of research conducted by Annex 31, a questionnaire was adapted from an earlier inventory by SPOLD on life cycle inventory databases. The questionnaire was sent to the databases providers. The results have been partially summarised in Table 2 and Table 3. Note that the third column "short description" allows readers to identify the approximate contents of each database. This description given by the database providers has been enriched when it was possible using two other sources: [Spo96] and [ÖBU97]. A more detailed examination and comparison of database content was beyond the scope of this research.

Country	Database name	Short description	Language	IEA contact	Author / Provider	Provider's Contact	Price	File / Format	Source
Canada	Statistics Canada	Embodied energy, water use & air emissions for 42 building materials	English French	S. Moffatt	Statistics Canada	http://www.statcan.ca	free downloading	Statcan97.doc Word 97	Quest
Canada	Canadian Raw Material Data Base	LCI data	English	S. Moffatt	Environment Canada	K. Brady T (819)953-1112	Handbook # 44 $	Rmdcn97.doc Word 97	Quest
Canada	ATHENA	Envir. LCA model used to assess commercial build. & assemblies	English	S. Moffatt	Athena Sustainable Material Institute	Jamie Mail T (613)722-8075		Athcan97.doc Word 97	Quest
USA	DEAM™ US	LCI db (US data), to be used with TEAM™ software	Engl.ish French	S. Nibel	Ecobalance	Vince CAMOBRECO T1-301-548-1750; Fx - 60	Depends on the needs	Deam_us. Doc Word 6	Quest
USA	Environmental Knowledge Base	Software tool for facility design, construction & operation	English	D. Fournier	US Army CERL, IL	d-fournier@cecer.army.mil		Envus97.doc Word 97	Quest
USA	BEES 1.0 for Win95	To evaluate building products according to environm. impact & economic assessments	English	D. Fournier		d-fournier@cecer.army.mil		Beeus97.doc Word 97	Quest
USA	LEED™	A green building rating system	English	D. Fournier		d-fournier@cecer.army.mil		Leedus97.doc Word 97	Quest
Japan	BRI LCA for buildings	Program calculating the energy use & CO2 emissions of a building	Japanese	Y. Konno	Jap. Build. Res. Inst.	yskonno@summiken.co.jp	1,000 Yen	Bri_Jn.doc Word 6	Quest
Japan	NIRE-LCA ver. 2	Education of LCA (refrigerator)	Japanese	Y. Konno	Atushi Inaba	yskonno@summiken.co.jp	free	Nire_jn.doc Word 6	Quest

Source : Quest : IEA BCS Annex 31 Questionnaire / SPOLD : Directory of LCI data sources Nov 1995 / ÖBU : LCA Software Guide 1997
Table 2: Non-European databases

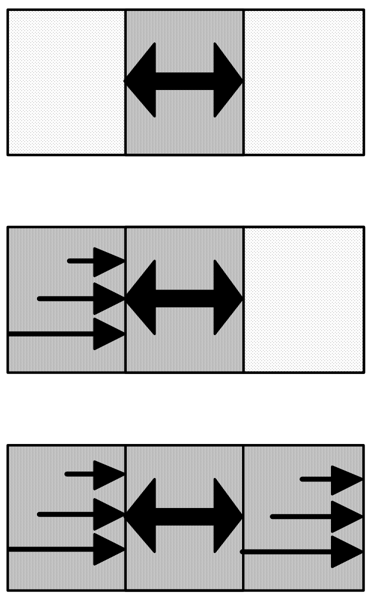
Country	Database name	Short description	Language	IEA contact	Author / Provider	Provider's Contact	Price	File / Format	Source
CH	Oekobase	LCI db embedded into a LCA software aimed to assess packagings	German	A. Lalive	Migros	Fx 41 1 277 30 88	8 500 CHfr	Oeko_ch.doc Word 6	Quest
CH	EcoInvent	LCI data for energy, transport & waste treatment for CH & Europe	German	A. Lalive	ESU-ETH / ENET	ENET Fx 41 31 352 77 56	125/200 CHfr	Esu_ch.do cWord 6	Quest
CH	REGIS 2.0	Site specific ecobalance software. 1000 items db : ETH en.syst. & w. treat., BUWAL 250, infras trp processes, etc.	Germ., Engl.	A. Lalive	Sinum GmbH Lerchenfeldstr. 5 CH-9014, St-Gallen	Dr Suzan Kytzia T+F x : 41 71 274 71 72 sinum@sinum.com	From 2 773 E	Regis_ch.doc Word 6	Quest + ÖBU
CH	OekoPro 1.5 (EMPA) BUWAL 250	Product-oriented LCA software. 1000 items db : ETH en.syst. & w. treat., BUWAL 250 pack. mat., infras trp processes, etc. LCI of packaging materials	German Engl.ish Ge/En/Fre	A. Lalive	EMPA Lerchenfeldstr. 5 CH-9014, St-Gallen BUWAL/OFEFP	Caroline Allenspach T 41 71 274 74 74; Fx - 79 docu@buwal.admin.ch	8500 CHfr (incl. VAT) 2500+VAT (educ) Buwal : 170CHfr	Oeko_ch.doc Word 6	Quest + ÖBU
DK	Edip	LCI db for energy sources, transport & industrial products	Danish	E. H. Petersen			125 DDK	Edip-dk.doc Word 6	Quest
DK	SBI's LCA DB & Inventory tool	db integrated into an LCI tool with uncertainty calculations	Engl., Dan.	E. H. Petersen	Danish Building Research Institute	www.sbi.dk	Free downloading	Sbi_dk.doc Word 6	Quest
F	DEAM™ EU	LCI db (European data), to be used with TEAM™ software	Engl., French	S. Nibel	Ecobilan M. P. Osset	posset@ecobilan.com T33(0)155696161; Fx - 69	Depends on the needs	Deam_eu. doc Word 6	Quest
D	GaBi 3	LCA software. 1500 items db: 30 plastics, 140 intermediate chem., 50 power plant processes, 50 transport, etc.	English German	K. Tanz, Th. Lützkendorf	IKP Universität Stuttgart	ikp2.uni-stuttgart.de/gabi or www.pe-product.de	7 160 E (std) 2 050 E (educ.)	Gabi.doc Word 97	SPOLD ÖBU
D	Heraklit 4.8	LCA software. 900 items db : energy syst., trp, waste tr ., raw mat., basic mat., mat. conversion, services, recycling	German English	K. Tanz, Th. Lützkendorf	Fraunhofer–Institut (ILV) Munich	Dr. G. Goldhan T 49 89149009 89; Fx - 80 ivv.fhg.de/euklid_e.html	6.65 - 15.4 kE site 9 -20.5 kE consult.	hera.doc Word 97	SPOLD ÖBU
D	TEMIS 2 (English) GEMIS 3 (German)	LCI tool. Few emissions for numerous energy & transport. proc. in sel. countries	English German	K. Tanz, Th. Lützkendorf	Öko-Institut Darmstadt	www.oeko.de/service/temis www.oeko.de/service/gemis	Free downloading since 1998 !	Temis.doc Word 97	
D	Umberto 2.0	LCA & site specific ecobalance software. 200 items db : en. syst., trp, sol. waste & waste wat. tr., raw & basic mat. (pack., etc.)	English German	K. Tanz, Th. Lützkendorf	IFU Hamburg	Dr Andreas Hauslein T 49 40 4620 33; Fx – 34 www.umberto.de	4 040 E (bus.) 1 280 E (educ.) 12 120 E (consul.) (+ VAT)	umb.doc Word 97	SPOLD ÖBU
NL	IVAM LCA Data 2.0	LCI building products oriented data (mainly Dutch) for SimaPro 4 software	English (Dutch)	Ir H.A.L. van Ewijk	IVAM Environmental Research	www.ivambv.uva.nl	750 E (+ VAT)	Ivam_nl.doc Word 6	Quest
N	Energi- og miljø-regnskap for bygg	LCI building materials data	Germ., Norw.	T. D. Petersen	Norweg. Building Research Inst., Oslo	Project report no. 173 (1995)		Nor_n.doc Word 6	Quest
S	SPINE@CPM	Data administration unit within CPM	English	W. Trinius	CPM, Chalmers Tekniska Högskola, Göteborg	Raul Carlson		paper	Quest
UK	The Boustead Mo-del for LCI calcul.	LCI software. 4500 items db : APME data for plastics, electr. For 23 countries, etc.	English	N. Howard	Boustead Consulting Ltd	Dr W.T. Dove, Chartham, Canterbury, Kent	10 000 £ / year	Boustead.doc Word 97	Quest

Source : Quest : IEA BCS Annex 31 Questionnaire / SPOLD : Directory of LCI data sources Nov 1995 / ÖBU : LCA Software Guide 1997
Price : E = Euro / kE = 1000 Euro
Table 3: European databases

Analysis of the data bases

There is a difference between process related, cumulative and life cycle assessment data. Only the combination of data sets and sets of hypotheses/allocations allows the establishment of life cycle related values.

Process related assessment takes the form of industry inventories. Cumulative assessments are based on a large number of assessments (inventories) of basic materials, energy related process, transport and disposal process. Life cycle related assessments can (in the case of buildings) only be made for whole buildings.



1 - Process related impact assessment

taking into account the inputs and outputs inside the system limits of a plant or process,

2 - Cumulative impact assessment

Taking into account all upstream and process related data (including direct emissions and waste).

3 - Life cycle impact assessment

Taking into account cumulated data and the probable future impact including all downstream process and transfer functions, based on scenario assumptions and space/time system limits.

Figure 1: LCA calculation types (source: REGENER)

As illustrated in Figure 1, the first LCA calculations were made purely on the basis of the final energy for building operation, which was linked to primary energy for each type of energy through primary energy coefficients. These coefficients came from national energy statistics or from input/output calculations. The primary energy in turn could be linked to emissions through emission coefficients for each type of energy. The results were emissions (mainly CO_2) and sometimes aggregated values. Resources were considered only as energy resources (primary energy).

In the next step, the embodied energy was taken into account mainly through the needs of primary energy to produce building materials. As a basis the quantities of building materials had to be estimated and through the mass flow material resources and waste quantities could be estimated. The main weakness of this approach was the difficulty to find data on embodied energy with clear indications of system limits. Today most of the published data is on this level.

The work of SETAC and the following standardization efforts made LCA a technique which could be applied to almost any study. As they are carried out, it is necessary to allocate comparable basic data, which would make it possible to aggregate inventories from different sources. The data sets provided from consistent process analysis on upstream phases (precombustion) and general commodities like transport allowed a modular approach. Furthermore the distinction between standard process emission and specific process emissions allows the comparison of process alternatives and can support optimization of products and processes. The results are emissions, aggregated values and resource consumption. This is the most used level of work of tools developed recently.

Recommendations

Recommendations for the users of databases

Inventory data versus inventory results - Why do we need good metadata?

We can apply the distinction explained above by REGENER to inventory data, which leads to an important distinction between what we call « inventory data », corresponding to elementary process related inventory data (case fig.1-1), and « inventory results », corresponding to the result of some cumulative inventory calculation (case fig.1- 2 or 3). Some databases contain inventory data, e.g. The Boustead database, and some other contain inventory results, like the APME inventory profiles for plastics manufacturing processes.

The first data are easy to adapt to the case under study, e.g. distance and means of transport, national electricity production, whereas the latter case must fit exactly the needs to be useful, since they cannot be adapted.

The need for metadata arises when one tries to identify the need for adaptation of inventory data or the adequacy of inventory results. This is one of the main reason for choosing a database with good metadata.
Now we can overview the databases available for each particular kind of process [Reg 97].

Energy preparation

The ECOINVENT [Fri 95] is the most detailed, complete and coherent public data set based on process analysis and REGENER proposes to use it. The system limits for inventories should be clearly reproducible and there should be a good data interface to assist in the choice of other data sets in the future. It could be interesting to compare the resulting emissions and aggregated values.

Energy use

There are standard average values for the type of fuel (e.g. natural gas), the type of transformation (e.g. low NO_x combustion), the size of the plant (e.g. less than 1MW) and the sector (e.g. industry). In general it is preferable to use these values instead of taking into account local emission measures which are in most cases not complete. There are problems when the energy transformation process is combined with chemical transformations (e.g. fluor emissions in brick production). The origin of the available data are databases from research projects and the older emission coefficients for energy transformation and materials (e.g. Handbook of industrial emission coefficients). In general these data are old and not coherent. They usually take into account only a few emissions (CO_2, SO_2).

For the European users, we agree with the authors of REGENER and recommend the use of ECOINVENT data for energy use as well as for energy preparation.

For the non-European users, TEMIS/GEMIS is reported by [SPO 95] as having being crosschecked with US EPA, DOE and IEA/OECD data. It can therefore be a good public free database, but the metadata available are far less detailed than for ECOINVENT.

For the US users, the editor of SimaPro 4.0 claims since mid-1998 to propose a comprehensive US database (see Web site www.pre.nl). DEAM US and Ecomanager are probably valuable data sources, but their very high price limits their availability, and their metadata have not been assessed.

For Eastern Europe users, CORINAIR provides air emissions factors for 22 pollutants and numerous energy-related processes, but they are averaged over 35 countries including all the Western European countries whose emissions factors are quite different.

For overseas users, little information is available. Data availability must be checked from local DOE, EPA and BRI [4].

For energy consumption REGENER proposes to use the UCPTE mix for electricity just as for material production and transport. It is possible to use a local mix for electricity consumed in situ (building site and use) as an additional decision criteria.

For some countries, like France, it is better to use a national mix for electricity consumed in situ since this mix is very different from the UCPTE mix. More generally, we suggest making a distinction between the electricity consumed in the manufacturing process of building products, for which data is often available at a regional level (e.g. Europe, North America, etc.), and the electricity consumed during the use phase of the building, which is accurately located. In the latter case a consumption mix should be calculated, taking into account import-export balance, since some small countries import a significant amount of their consumption of electricity. For largely exporting countries like France, the consumption mix is quite similar to the production mix and such a distinction is not relevant. On the other hand, a European electricity mix like the UCPTE mix is in some cases far from reflecting the reality of a national mix, such as the French one.

TRANSPORT

Transport process emissions should include the infrastructure. It is the only way to be able to compare systems. REGENER proposes to take the transport relevant data from the same source (ECOINVENT). We propose to update these sources using the more recent emission data of GEMIS 3.0.

DOWNSTREAM PROCESSES

Disposal or transfer functions do exist per waste category but only for a few particular materials and technologies. Data for waste exist in ECOINVENT, in IVAM 2.0 and in recent publications [Bra95]. There are at present research projects going on in several countries. In future there will be more data from inventories of producers concerning materials.

REGENER proposes to use the ECOINVENT data per waste type. We suggest using the IVAM 2.0 data base, which is much more complete than ECOINVENT concerning waste treatments and remains compatible with it since it uses the same list of substances.

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4 DOE : Department of Energy, EPA : Environmental Protection Agency, BRI : Bulding Research Institute.

BUILDING MATERIALS

There are many literature values for embodied primary energy. REGENER proposes not to use these data any more, since their system limits are unclear and the data is out of date in general. REGENER proposes to use [for German-speaking countries (Germany, Switzerland and Austria)] the public database ÖKOINVENTARE BAUSTOFFE [Ifi 95]. The Dutch IVAM 2.0 database contains also many data from different sources with rather well documented metadata. Their relevance for countries other than the Netherlands has however not been assessed.

RECOMMENDATIONS FOR THE DATA BASE DEVELOPERS

Metadata

The database developers are strongly invited to read the preceding paragraph entitled "Recommendations to the users of databases". It is shown there what are metadata and why good metadata are of utmost importance.
Presented and commented on below is the improvement program proposed by REGENER. In the following paragraph, the indented text in italics comes from [Reg 97].
The next step of LCI data base development will consist in several improvements:

1. the distinction between average technology and best technology on the level of inventories
2. the introduction of data exchange formats for inventories [Spo 96] which will considerably enlarge the modular approach.
3. the calculation of the overall upstream resource consumption with new system limits. This approach which is also called mass burdens [Wup95] combines process analysis and input/output analysis.
4. the completion of aggregated values by external cost, above all for non energy related impacts which are important in the case of buildings
5. the link of inventories with data on toxicity of materials (above all auxiliary materials which make less than 5% of the weight of materials). This will allow an appreciation of the human toxic impacts. The estimation of dissipation (and concentration) of toxic materials through recycling will become possible.

Each of these points is expanded on below:

Point 1: To distinguish the technology level

Point 1 is sometimes the subject of vigorous discussion by product manufacturers, who would prefer to make a distinction between "current technology" and "obsolete technology". Indeed, for many industrial sectors the techniques of pollution reduction are well known but very expensive, and their implementation is planned in their future long-term investment plans, often resulting from negotiation with governments and/or representative bodies, e.g. European Assembly. Therefore the correct approach is a scenario approach, taking into account the planned improvement of the emissions factors of the industrial sectors. The databases should be able to cope with this kind of approach (i.e. prospective data).

Point 2: To use standard data exchange formats

To fulfil point 2 of this program, the developers may use the following tracks:

- **The SPOLD common format and data network**

The Society for the Promotion of LCA (SPOLD) has developed a common format for LCI data, to facilitate data exchange and improve quality. Besides the « classical » input/output flows, the format contains descriptive data (metadata): subsystem structure, boundaries, quality, representativity, energy/transport/waste models, supporting the choice of relevant data sets. An electronic version can be free of charge

downloaded from the Internet, together with the paper specifications and an example (http://ipt.dtu/dk/~bow). Otherwise the structure of the SPOLD common format is essentially described in [Spo 96].
In spring 1999, the society openned the SPOLD data Network (SDN), to offer a central contact point with an electronic directory of all LCI data available, the data itself remaining on the decentralised database servers of the data suppliers. This network is developed and hosted by IPU (Institute of Product Development), Techn. Univ. of Denmark, DK-2800 Lyngby.

- **The Equity Data Model (EDM)**

The Department of Materials of CSTB (the French BRI) at Grenoble has developed a generic, conceptual object-oriented LCA data model called Equity Data Model. Written using ISO/STEP EXPRESS, a standardized language that provides the automatic treatment of computer implementation, EDM permits the definition of partial aggregation levels and a selective information display, qualitative data consideration, backtracking from valuation results to preliminary data and exportability. A computer implementation has been developed for internal use only, but the conceptual model is independent of its implementation and is available in [Fer97]. It will be published into a well-documented form during year 1999.

- **The Spine specifications**

A relational database structure named SPINE (Sustainable Product Information Network for the Environment) has been developed in Sweden by IVL, the Swedish Environmental Research Institute, Chalmers University of Technology and Chalmers Industriteknik (CIT), in order to allow communication between different software tools, in particular the Swedish « EPS system » and CIT's « LCA Inventory Tool ». SPINE is described in a standardised way in a SQL-code and may also be used as a common language for LCA data structures, although to understand it it is necessary to be familiar with the SQL-code datamodel description language.

The data suppliers in the SETAC Europe workgroup on data availability and data quality created recently an « implementation » subgroup, on the basis of the SPOLD and the SPINE formats.

Point 3: How to combine process analysis and input/output analysis

Emissions factors provided by input/output analysis are poorly exploited by LCA inventories, at least in Western Europe. CORINAIR provides useless averaged data (see above), and the emission factors provided on the Web by the US EPA are valuable for USA only. Site emission data which are generally collected in developed countries for pollution control purposes could feed LCI data bases and updating procedures should be established from national control measurement programs. The data base developers could both participate in the theoretical work on this problem and ask the competent national and international bodies for publishing statistical pollution data to be able both to respect industrial confidentiality and to feed LCI data bases.

Point 4: To integrate non energy related external cost

Although this point is beyond the scope of this annex, we will just mention here that this is an important topic, which is *de facto* taken into account when using some exhaustive data bases like ECOINVENT with general purpose LCA software tools.

Point 5: To link inventory data with toxicity data

The potential and general non site-specific characteristics of the LCA approach mismatch the site specific and target specific aspects of substances toxicity. Several theoretical "environmental impact assessment" developments are attempting to encompass these limitations. Among them, the "critical surface-time approach" seems to be able to provide useful results for data base developers, presented in [CST 97a & CST 97b].

Recommendations for the developers of tools including data bases

1. The LCA software tools including databases should satisfy the requirements of the SPOLD format to be able to cope with comprehensive sets of metadata.
2. Since most of the LCA tools now allow users to modify or implement new impact assessment methods, they should allow the user to implement their own data quality indicator system, since there is not yet any well-recognised standard system.
3. Because of the high specificity of a building and of building products, a building-oriented impact assessment software tool should be able to communicate with external tools devoted to e.g. calculation of heating energy consumption, of natural lighting (to assess the needs of artificial lighting), of internal air quality and hygro-thermal comfort, etc.
4. Taking into account the high variability of many inventory data, they could implement the technique developed by Le Téno [LeT 96] to calculate using value intervals or any other quick and easy to understand uncertainty or sensitivity analysis [5].
5. To use existing conceptual models like SPINE [Spi 96] and EDM [Fer 97] and to publish their own data model will help to develop interface with software performing complementary assessments like energy consumption during the use phase of the building, etc.

[5] JF Le Teno and ETH consider that the intervals are the best-suited way to take into account data uncertainty, since they allow to model the shimmy at the exact level the data are available. This is not the case of other techniques like fuzzy sets or probability distributions, which need more information than available.

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