LCA Case Studies

A Screening Level Life Cycle Assessment of the ABB EU 2000 Air Handling Unit

Jens Brøbech Legarth[1*], Stellan Åkesson[2], Alena Ashkin[3**], Anne-Marie Imrell[3]

[1] RAMBØLL Energy & Environment, Teknikerbyen 31, DK-2830 Virum, Denmark
[2] ABB Ventilation Products AB, Division Fläkt, S-551 84 Jönköping, Sweden
[3] ABB Corporate Research, S-721 78 Västerås, Sweden

* Contact for the screening level LCA method
** Corresponding author at ABB Corporate Research

Corresponding author: Jens Brøbech Legarth; e-mail: JRL@RAMBOLL.DK

DOI: http://dx.doi.org/10.1065/lca199911.004

Abstract. The screening level LCA places itself amongst the many approaches to LCA, including full LCA and streamlined LCA. The screening level LCA combines the quantitative nature of the full LCA with the low effort of the streamlined LCA. This paper presents, as an example, a screening level LCA of the EU 2000 air handling unit from ABB Ventilation Products AB, Sweden, using the Danish EDIP impact assessment method, the EDIP software and database. This study proved that major improvement potentials can indeed be identified with screening level LCA, and argues that the screening level LCA is a suitable approach in the early stages of a company's life cycle engineering efforts.

Keywords: ABB Ventilation Products; active product; full LCA; EDIP method; impact assessment; industrial ecology, life cycle assessments; life cycle engineering; screening level LCA; streamlined LCA

1 Introduction

The global development we face today with a growing world population and with a legitimate demand for wealth has put a focus on environmental and resource issues, particularly through the last decade. We are threatening to exhaust the planet's so-called environmental space, e.g. the stocks of natural resources and the amount of pollution the earth can cope with. To counteract this development, the concept of sustainable development was already introduced in 1987 in the Brundtland report [1]. This concept calls upon all actors in industrialised societies to enter into such activities that "meet the needs of the present without compromising the ability of future generations to meet their own needs". The industrialised civilisation and not least the industrial community is now struggling to come to terms with the true meaning of this statement.

It has long been recognised that the concept of sustainable development calls, not least, upon the industrial community to create more wealth using less resources and with fewer adverse effects on the external environments, and that a new support concept for sustainable industrial production has been born: The life cycle concept. The life cycle concept puts the product and its life cycle in focus in product design-based pollution prevention. We now talk about life cycle engineering and design.

New decision support tools have also been developed. We have become familiar with such terms as life cycle assessment (LCA), streamlined life cycle assessment (SLCA), life cycle cost assessment and design for disassembly (DfD). The debate on procedures and methodologies for these decision support tools is still going on in the international community, and no real consensus has been fully reached, for example, for environmental impact assessment. Industry itself is still debating which of these support tools is best suited for industrial applications, given a demand for quick and low-cost decision support.

This paper presents a screening level LCA study of a large metal structure, the EU 2000 air handling unit from ABB Ventilation Products AB, Sweden. The LCA method used here, specifically the impact assessment method, is the Danish EDIP method [2,3]. The study is an example of a practical LCA study which can be performed in a few days, given the right inputs. These inputs are a bill of materials, environmental reports for major manufacturing sites, an export scenario, a use stage definition and a disposal/recycling scenario. The procedure requires an extensive LCA database and a quantitative LCA software tool.

This LCA is performed as part of the Remproduse-Cu project under the European Commission's Environmental & Climate Programme. The Remproduse project looks into the possibilities of increasing copper recovery from electric motors through the innovative design of electric motors and the design of suitable disassembly systems [4].

2 The ABB EU 2000 Air Handling Unit

The ABB EU 2000 air handling unit is a standard ABB product. It is shown in **Fig. 1**. The selected unit consists of six modules. These are comprised of an air heater, an air cooler,

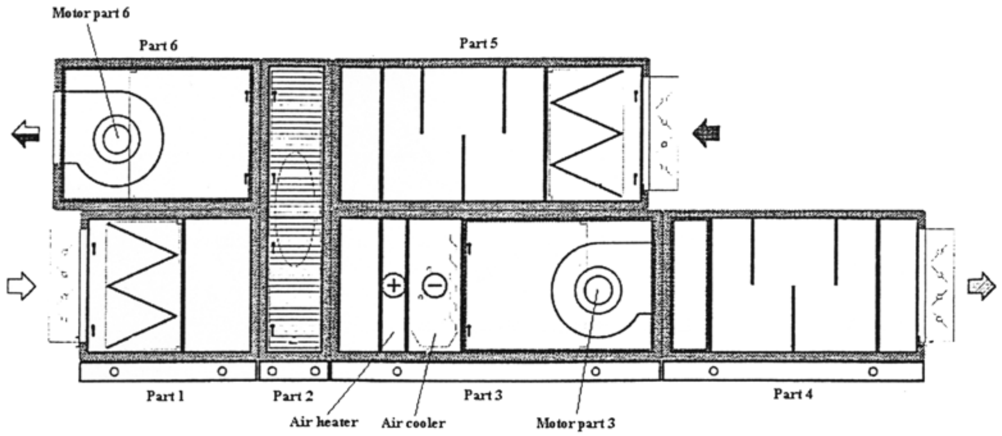

Fig. 1: The ABB EU 2000 air handling unit. Both fans have electric motors

a rotary heat exchanger, filters, silencers, two fans with large size motors and the hull. Due to the copper content, the air heater, air cooler and the two motors have been treated as separate parts.

The product materials breakdown is shown in Table 1. The product is largely metallic (various kinds of steel, aluminium, copper), with some mineral wool and glass wool and minor amounts of plastics, rubber, glue and glass-fibre tissue.

Table 1: Material breakdown of the ABB EU 2000 air handling unit

All weights in kg	**Part 1**	**Part 2**	**Part 3**	**Part 4**	**Part 5**	**Part 6**	**Air Heater**	**Air cooler**	**Motor part 3**	**Motor part 6**	**Sum**
Carbon steel	38.0	45.3	65.9	45.0	49.0	56.9	5.2	6.6	23.1	18.1	353.1
Galvanised steel	134.5	114.7	271.1	214.3	213.5	177.6	23.0	33.5			1182.2
Electroplated steel		6.7									6.7
Electroplated carbon steel		2.2									2.2
Copper		0.3					5.0	10.0	4.4	3.0	22.7
Cast copper		0.2									0.2
Aluminium		97.0					5.0	12.0	1.0	1.0	116.0
Cast aluminium	3.0	14.2	3.0	3.0	3.0	3.0			7.3	4.7	41.2
Stainless steel			0.1			0.1		12.5			12.7
Rubber	0.3	0.1	2.0	0.3	0.3	2.0					5.0
Various plastics	0.5	0.8	1.8	0.5	5.6	2.2		5.0	0.2	0.2	16.8
Mineral wool	14.0	5.4	26.0	20.0	25.0	16.0					106.4
Glue		7.6									7.6
Glass-fibre tissue	5.0										5.0
Glass wool				32.0	32.0						64.0
Total weight											**1941.8**

3 The Study

This section discusses the actual LCA study, scope and goal definition, inventory and modelling as well as impact assessment. In doing this, the screening level LCA adheres to the guiding principles of comprehensive, full LCA. The Danish EDIP LCA method is used throughout the study [2,3].

3.1 Goal definition and scope
Definition of goal

The intended use of this screening level LCA is threefold. Firstly, to see if the characteristics of draw on copper stock are important for large industrial motors in an industrial product. Secondly, if the draw on copper stock is indeed important for the study object with its two large electric motors, to let the study act as a basis for further assessments of re-designed products with the same basic performance and function. Thirdly, the purpose of the study is to provide ABB Corporate Research with a screening level LCA study of an ABB product using the Danish EDIP LCA methodology. (ABB has its own LCA tool, developed by ABB Corporate Research, and based on partially different models.)

A number of decisions can be made on the basis of the results of this study. The study may form the platform for a subsequent environmental diagnosis step in which the product's, and particularly the motors' potentials for environmental improvements can be uncovered.

The target group for this study is first and foremost the partners of the Remproduse-Cu project, particularly the industrial partner, ABB, and the partners involved in motor redesign. Secondly, the target group comprises manufacturers of industrial products that might in the future wish to pursue a screening level LCA approach in an identification of improvement options.

The present study is a part of task 2 in the three year Remproduse-Cu project which is financed by the European Commissions Environment & Climate Programme [4]. There are no other financial ties than the above, and the study is a scientific study with no principal commercial aim. The study was conducted in 1997 by Jens Brøbech Legarth at the Department of Manufacturing Engineering of the Technical University of Denmark. The study was subject to internal review by other staff members.

Definition of scope

The object of this study is the EU 2000 air handling unit from ABB Ventilation Products AB in Sweden. The product has been described in a previous section. The function of the product is to supply treated air in typically larger houses, apartment buildings and ships. This is the only function of the product. The functional unit is the treatment of one cubic meter of indoor air, although the purpose of the study is not to compare this product with other air handling products, but rather to identify absolute improvement options for the EU 2000 unit. The results later in this paper are therefore not directly presented per functional unit, but per product. The bill of materials is shown in **Table 1**.

The study output states the potential impact of the whole air handling unit in the following impact categories: Global warming, ozone depletion, acidification, nutrient enrichment, photochemical ozone formation, waterborne toxicity towards humans, airborne toxicity towards humans, acute waterborne toxicity towards eco-systems and chronic waterborne toxicity towards eco-systems. The following waste categories are included: Hazardous waste, radioactive waste, slag and ashes, and volume waste. And the following categories of stock depletion are included: Depletion of stocks of lignite (brown coal), natural gas, crude oil, coal, aluminium, iron, manganese, copper and zinc.

System boundaries are set as follows. The life cycle of the product covers all life cycle stages: Raw material production, pre-manufacturing, manufacturing, distribution, use, disassembly and recycling/disposal. Please note that distribution is the only transportation step included, since almost all pre-manufacturing takes place within short distances in Sweden, which makes distribution by far the most important transportation contribution. It is further shown that transportation has a very small share of the total environmental impact. The process system is portrayed in **Fig. 2**.

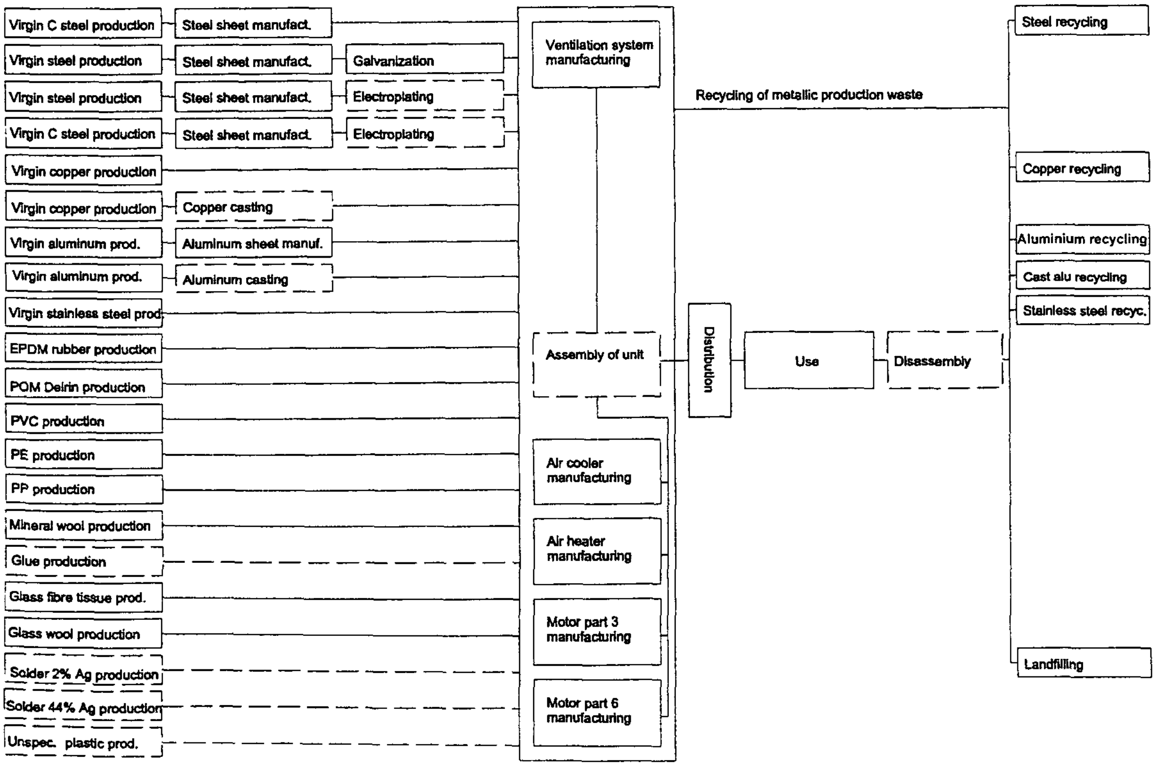

Fig. 2: The ABB EU 2000 air handling unit process system

The raw material production stage goes up-stream all the way "to earth", i.e. includes all processes up-stream until and including oil extraction or extraction of minerals and metal ores. No renewable resources are used for materials. All processes from the metal ore extraction up to the metal ingot have inputs of energy and require materials and outputs in the form of emissions. These vertical inputs and outputs are included in the inventory segments for the materials.

The pre-manufacturing life cycle stage covers all processes between the delivery of the raw material and the entry of parts and components (e.g. sheet metal) into the manufacturing facilities of ABB. Examples are steel sheet manufacturing or copper forming into wires, tubes, etc.

The manufacturing of the air handling unit from raw materials, parts and components is all taking place within the ABB corporation. Motors are produced by ABB Motors AB, air cooler and air heaters by ABB Coiltech AB and the production of the other parts plus assembly takes place within the ABB division of Ventilation Products AB. All manufacturing facilities are located in Sweden. Metallic production waste is assumed to be recycled, whereas non-metallic production waste is neglected, as the amounts are quite small.

Distribution to end users from ABB Ventilation Products AB, Sweden is included, as is the product's use stage.

The disposal life cycle stage is assumed to be disassembly based, also regarding the (large) electric motors. The reason for this assumption is that the metal value of the air handling unit and the motors is large enough to secure this type of disposal scenario in virtually all of the countries the EU 2000 units are sold in. All metals are assumed to be recycled, and all non-metals are considered to be land filled.

Capital equipment is not included in the study, which is valid for a period of about 3-4 years.

The process system in **Fig. 2** includes both virgin raw material production and recycling. Because all metallic parts are assumed to be recycled, the virgin raw materials for this product are used in more than one product, and an allocation is necessary for the environmental effects and depletion of stocks associated with virgin raw material production on the one hand and for those associated with a final disposal of these materials in land fills some time in the future, on the other. In plain terms, this means that it is not fair to let the EU 2000 unit "pay" fully for the virgin raw materials if this product is merely the first but not the only user of the material. Furthermore, recycled metallic raw materials will eventually end up in a land fill, as slag, end-of-life products or in other forms, and the EU 2000 unit should also only "pay" partly for this land fill space occupation, and indeed for the environmental effects associated with land filling. The processes truly common to the EU 2000 unit and future products are virgin raw material production processes, excluding pre-manufacturing, as well as the final land fill process. Recycling processes are not seen as common processes in the EDIP method's allocation philosophy, and the EU 2000 unit has to "pay" for the recycling in order to get the "discount" on the common processes of virgin raw material production.

There are two basic allocation situations that apply to the present study, namely a situation where the raw material is virgin raw material that is subsequently recycled, and a situation where the raw material is a recycled material that is subsequently recycled further at this product's end-of-life. **Fig. 3** and 4 show the basic material flows for these two situations.

The variables in **Fig. 3** indicate the material flow for each kilogram of the material in the product. The factor "a" is the production waste divided by the amount of that material in the product (all production waste is assumed recy-

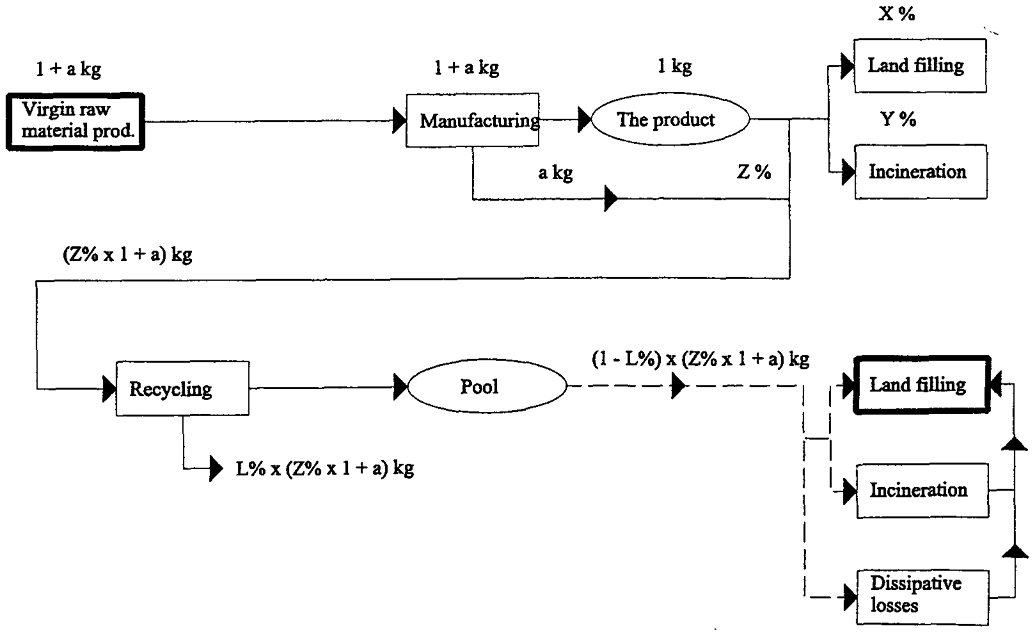

Fig. 3: Allocation, according to the EDIP method, for virgin stock that is recycled at product end-of-life. Fat boxes show common processes

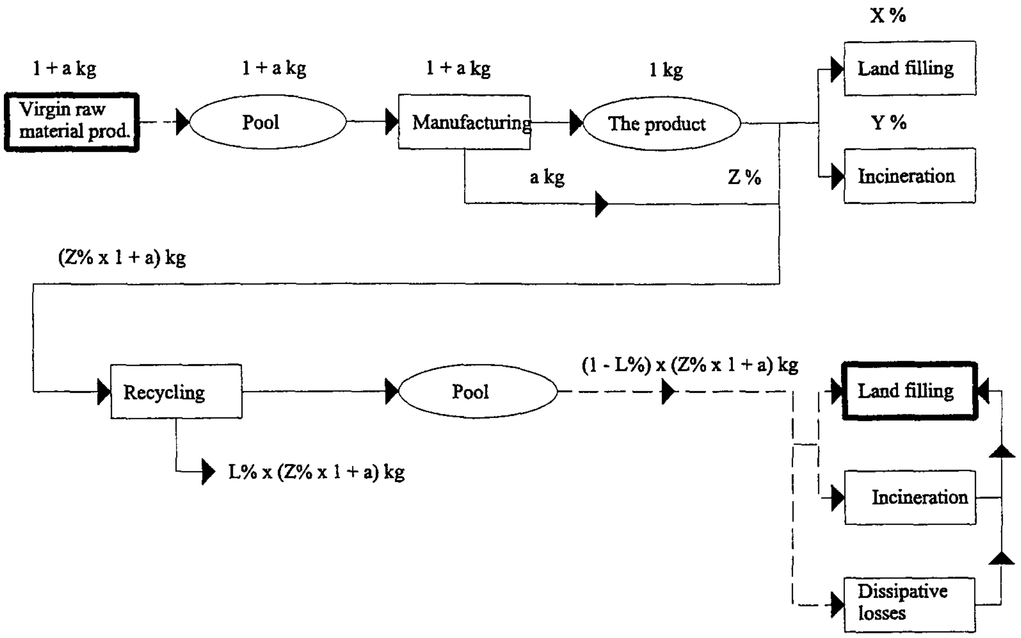

Fig. 4: Allocation for recycled stock that is further recycled, according to the EDIP method. Fat boxes show common processes

cled), and the factor "a", thereby, is not a waste percentage, but takes on higher values than the corresponding waste percentages. The factors "X", "Y" and "Z" are percentages of the total production volume that go to land fill, incineration and recycling, respectively. "Z" thereby addresses the fraction of the production volume which is recycled after terminated use. In the present study all products go to recycling and Z takes the value of 100%. The factor "L" is the loss of material in the recycling processes. For metals, this is typically a loss to slag in metallurgical refining processes.

The shares of the EU 2000 units in the two common processes are both calculated using the same formula:

(N kg in product) x (L(Z+a) + fgrade loss x (Z+a)(1-L))

where fgrade loss is the so-called loss of grade for the material when passing one time through the contemporary average recycling process for the material in question. The grade for a virgin material is 1.0 and grade is a measure of utility value. For a deeper discussion of the concept of grade, the reader is referred to [2]. Please remember that the factor Z takes the value of 100% or 1.0.

Fig. 4 shows almost the same picture, but now the raw material is a recycled material drawn from a pool of recycled material. The principle of the notation in Fig. 4 is the same as in Fig. 3. The formula for the share of the ABB EU 2000 unit in the two common processes, in this case, is as follows:

(N kg in product) x (L(Z+a) x fscrap + fgrade loss x (Z+a)(1-L))

where fscrap is the average grade of the recycled material in the pool, typically taking a value of less than 1.0.

The EDIP allocation method is in accordance with ISO recommendations. A technically-based allocation is used for this study.

3.2 Inventory and modelling

This section is about the gathering of baseline data, the inventory, and about how it has been performed practically, i.e. how the EDIP database and the EDIP modelling tool have been used [5]. The inventory is presented at the end of this section.

The total pre-manufacturing life cycle stage (raw material extraction and other pre-manufacturing), in principle, covers all processes, for example, from the extraction of metal ore from the ground to where the materials enter the ABB production facility. The backbone of the handling of the pre-manufacturing stage is the material input to the ABB production facility, i.e. the materials that make up the product plus production waste. In the present case, the production of most materials covers processes "back to earth", e.g. environmental interactions are included for all processes going back to ore extraction for example. This goes for the various kinds of steel, aluminium and copper, as well as for EPDM rubber, glass-fibre tissue, glass wool, mineral wool, POM, PVC, polypropylene and polyester tissue. The production of solders, unspecified plastics and glue has not been modelled due to lack of information. This means that no statements can result from the study about these materials.

The modelling in the EDIP tool is quite simple. When a raw material is chosen in the material database, and an amount is assigned, the tool includes all effects back to earth by itself. Since the life cycle scenario for the ABB EU 2000 unit includes the recycling of metallic materials, the present life cycle shares the metallic materials with future product life cycles. For this reason, only a limited fraction of the total amounts of metallic material entering ABB Ventilation Products, ABB Motors or ABB Coiltech belongs to the present product – this amount is determined by the allocation formulas above. All metals apart from cast aluminium are virgin materials. The allocation results are only valid for the true virgin raw material production processes. Other pre-manufacturing processes such as steel sheet forming or copper casting belong fully to the EU 2000 product, and the amounts shaped are the material in the product plus production waste.

Please note that the factor "a" in Tables 2-4 is not a waste percentage, but rather the waste amount divided by the amount of that material in the product, thus, the high numbers.

Table 2: Allocation for parts 1-6, virgin raw material production

Material	Amount in parts 1-6	a in%	f scrap	f grade loss	L	Allocated amount	Virgin stock
Carbon steel	300.1 kg	34.41	0.85	0.10	0.03	51.22 kg	Yes
Galv. Steel	1125.7 kg	34.41	0.85	0.10	0.03	192.15kg	Yes
Cast aluminium	29.2 kg	0.00	0.80	0.10	0.03	3.52 kg	No
Electroplated steel	6.7 kg	26.43	0.85	0.10	0.03	1.08 kg	Yes
Copper	0.3 kg	0.00	0.90	0.05	0.01	0.02 kg	Yes
Aluminium	97.0 kg	19.94	0.80	0.10	0.03	14.78 kg	Yes
El. plated carbon steel	2.2 kg	26.43	0.85	0.10	0.03	0.37 kg	Yes
Cast copper	0.2 kg	0.00	0.90	0.05	0.01	0.01 kg	Yes

Table 3: Allocation for air heater/air cooler, virgin raw material production

Material	Amount in motors, total	a in%	f scrap	f grade loss	L	Allocated amount	Virgin stock
Carbon steel	41.2 kg	55.52	0.85	0.10	0.03	8.13 kg	Yes
Copper	7.3 kg	6.38	0.90	0.05	0.01	0.47 kg	Yes
Aluminium	2.0 kg	0.00	0.80	0.10	0.03	0.25 kg	Yes
Cast aluminium	12.0 kg	0.00	0.80	0.10	0.03	1.45 kg	No

Table 4: Allocation for motors, virgin, raw-material production

Material	Amount in motors, total	a in%	f scrap	f grade loss	L	Allocated amount	Virgin stock
Carbon steel	41.2 kg	55.52	0.85	0.10	0.03	8.13 kg	Yes
Copper	7.3 kg	6.38	0.90	0.05	0.01	0.47 kg	Yes
Aluminium	2.0 kg	0.00	0.80	0.10	0.03	0.25 kg	Yes
Cast aluminium	12.0 kg	0.00	0.80	0.10	0.03	1.45 kg	No

The manufacturing life cycle stage for the ABB EU 2000 unit has been handled essentially as ten aggregated processes, one for each of the parts 1-6 that make up the hull, one for the air cooler, one for the air heater, and one for each of the two motors. Instead of looking specifically at each individual manufacturing process, a black box approach has been adopted, where the input/output data from the environmental reports of ABB Ventilation Products, ABB Coiltech and ABB Motors, respectively have been used as a basis for an assessment of the environmental interactions from production of the hull, heat exchanger, silencers, filters, air heater/cooler and motors. A simple allocation principle was used, based on the weight of galvanised steel for parts 1-6, the weight of galvanised steel for the air heater/cooler and the weight of copper for the motors.

The resulting inventory includes all inputs and outputs listed in the environmental reports. However, in the modelling, some inputs and outputs have been neglected because the EDIP database does not support them, or because they are considered environmentally insignificant due to the low amount and few environmental interactions. For parts 1-6, these include the inputs of the aiding materials and chemicals of glue (solvent, resin, polymer) and the solvent based on MEK and acetone, all unsupported by the data base, as well as various small amounts of oils, fats, degreasers, ammonia and gas, all considered without significant environmental interactions. For parts 1-6, all emissions considered to be hazardous and other wastes have been included in the modelling, as have all emissions to water and all emissions to air, including those associated with the burning of gas in welding, etc. All counts of energy consumption are included, electricity is taken as the Swedish average.

The total consumption of aiding materials and chemicals is accounted for, apart from glue and degreaser, (some chemicals, however, simply as "refined oil products" – a collection category), in the modelling of these inputs for the production of the air cooler and the air heater at ABB Coiltech. Most gas consumption has been included, apart from acetylene. All emissions to air, water and as waste have been included. This goes for energy consumption as well. Also here, electricity is taken as the Swedish average.

The same general guidelines apply to the modelling of the motor production at ABB Motors. The omissions made in order to achieve a practical modelling of the manufacturing life cycle stage limit the conclusions of the study to statements about those manufacturing stage emissions included in the modelling, as no impact assessment has been performed for omitted substances.

Transportation is modelled only by distribution, and this in turn by a simple model, as a total of 1,106,254 kgkm of lorry transportation (lorry carrying more than 16 tons on freeway) and 1,672,493 kgkm of container carrier transportation (28,000 DWT), based on data supplied by ABB Ventilation Products. The transportation life cycle stages have not been considered thoroughly, since it is well known from other studies on highly active products that the totality of transportation does not correspond to any significant environmental load compared with the rest of the life cycle stages.

The use life cycle stage is modelled as follows: The ABB EU 2000 unit is a highly active product. ABB Ventilation Products has estimated the life time to 20 years on average, and calculated the energy consumption to a total of 37,771 kWh per year, of which 24,289 kWh are used for the motors, 10,349 kWh for the heat coil and 3,133 kWh for the cooling coil. The energy source is purely electricity for the motors and the cooling coil, and 50% electricity, 30% natural gas and 20% oil for the heating coil on average across the total sales volume (different energy sources for different unit installations). The fossil fuels are used directly with a very high efficiency, taken for simplicity as 100%. The 100% are an assumption, and a deviation would impact the assessment of the environmental load for the use stage somewhat. The objective of this study, however, is not to represent the actual environmental load precisely, but to identify major improvement options. Conclusions related to this objective, however, are not significantly affected by this assumption.

The export scenario is modelled by simply dividing sales into the categories Sweden (33.3%), EU countries other than Sweden (37.1%), rest of the world (9.1%) and marine uses (20.5%). Electricity consumption is taken as Swedish electricity, EU average electricity and world average electricity, respectively, whereas marine electricity is assumed to be generated on the spot by a diesel generator with 30% efficiency.

It is assumed that there are no environmental interventions except for energy consumption during use.

The disposal scenario for the ABB EU 2000 unit is fully disassembly based, as mentioned before. This means in practice that all metal parts are recycled on all markets. In the nature of things, it has not been possible to verify this assumption, which is essentially an educated guess based on knowledge about the disposal industry and the product. The motors are sufficiently large to make disassembly with full metal recovery economically viable. All non-metal parts are assumed to be land filled. Please note that the allocation models shown in Fig. 3 and 4 assume that all metal drawn from virgin stock will eventually end up in a land fill as well, for example due to dissipation losses and losses from recycling. A part of this land-filled metal amount belongs to the present product, and this amount is exactly the same as the amount allocated as virgin raw material production. Thus, the disposal scenario for the ABB EU unit involves both recycling processes that belong fully to the present product, and land filling of non-metal parts and metal recycling waste products, for instance.

The actual disassembly operation is assumed to have no significant environmental interventions.

The total inventory for the model product is presented in **Tables 5-8**.

Table 5: Emissions to air, inventory level, full ABB EU 2000 unit life cycle

Substance	Emission	Substance	Emission
Aluminium (Al)	10.0 g	Hydrocarbons (HC)	1010000 g
Aliphatic carbons	134 g	Hydrogen chloride (HCl)	385 g
Aluminium oxide (Al_2O_3)	410 g	Hydrogen fluoride (HF)	5.72 g
Ammonia (NH_3)	0.221 g	Hydrogen sulfide (H_2S)	38.7 g
Argon (Ar)	1400 g	Methane (CH_4)	12700 g
Aromatic carbons	63.8 g	Manganese (Mn)	40.2 g
Arsenic (As)	15.1 g	Nickel (Ni)	155 g
Carbon dioxide (CO_2)	318000000 g	Nitrogen oxide (NO_x)	2030000 g
Carbon monoxide (CO)	941000 g	NMVOC	254000 g
Cadmium (Cd)	1.91 g	Oxidated carbons	4730 g
CFC 502 [a]	2.81 g	PAH	1.34 g
CFC 12 [a]	0.615 g	Lead (Pb)	22.9 g
Chloride (Cl^-)	4.36 g	Selenium (Se)	5.85 g
Chromium (Cr)	6.49 g	Styrene	36.4 g
Copper (Cu)	16.4 g	Sulphur dioxide (SO_2)	1870000 g
Dinitrogenoxide (N_2O)	15500 g	Sulphuric acid (H_2SO_4)	0.266 g
Fluoride (F^-)	11.1 g	Vanadium (V)	478 g
HCFC 22	28.3 g	Other VOC	6150 g
Mercury (Hg)	2.78 g	Zinc (Zn)	75.4 g

[a] CFC emissions come from cooling of manufacturing equipment – there are no CFCs in the product itself.

Table 6: Solid waste emissions, inventory level, full ABB EU 2000 unit life cycle

Waste category	Emission	Waste category	Emission
Aluminium (Al)	839 g	Unspec. rubber	199 g
Aluminium oxide (Al_2O_3)	7850 g	Unspec. industrial waste	36.0 g
Dolomite	16500 g	Unspec. chemical waste	21800 g
Iron (Fe)	1250 g	Unspec. oven slag	889 g
Iron rich oven slag	41100 g	Unspec. radioactive waste	858 g
Quartz	72.8 g	Unspec. salt	20900 g
Mineral waste	55.1 g	Unspec. slag & ashes	20.0 g
Sodium hydroxide (NaOH)	1.98 g	Unspec. slag & ashes, energy	6120000 g
Sand	123 g	Unspec. slag & ashes, incineration.	2.54 g
Unspec. waste from steel prod.	37600 g	Unspec. sludge	0.0023 g
Unspec. bauxite waste	72800 g	Unspec. dust with heavy metals	796 g
Unspec. hazardous waste	489 g	Unspec. volume waste	22500000 g

Table 7: Emissions to water, inventory level, full ABB EU 2000 unit life cycle

Substance	Emission	Substance	Emission
Aluminium (Al)	0.971 g	Hydrocarbons (HC)	1060 g
Ammonia (NH_3)	1.61 g	Hydrogen fluoride (HF)	0.0218 g
Arsenic (As)	0.439 g	Manganese (Mn)	0.0907 g
BOD	272 g	Sodium ions (Na^+)	735 g
Calcium (Ca)	2.94 g	Ammonia-nitrogen (NH_4-N)	420 g
Chloride (Cl^-)	2480 g	Nickel (Ni)	5.09 g
Chromium (Cr III)	0.0262 g	Nitrate-nitrogen (NO_3-N)	237 g
COD	1740 g	PAH	0.0051 g
Chromium (Cr)	4.74 g	Lead (Pb)	0.450 g
Copper (Cu)	1.73 g	Phenol	10.6 g
DOC	333 g	Selenium (Se)	0.0049 g
Iron (Fe)	161 g	Suspended solids (SS)	1160 g
Fluoride (F^-)	799 g	Sulphate (SO_4^{--})	471 g
Phosphate (PO_4^{---})	3.73 g	TOC	0.764 g
Hydrogen ions (H^+)	2260 g	Zinc	2.81 g
Mercury (Hg)	0.0011 g	Cadmium (Cd)	0.298 g

Table 8. Resource draws, inventory level, full ABB EU 2000 unit life cycle

Resource	Draw	Resource	Draw
Aluminium (Al)	28100 g	Dammed water	78500000000 g
Lignite, fuel	19800000 g	Surface water	19.3 g
Calcium carbonate ($CaCO_3$)	56300 g	Crude oil, fuel	50300000 g
Copper (Cu)	1450 g	Crude oil, raw material	14500 g
Iron (Fe)	277000 g	Sulphur (S)	181 g
Ferro manganese	0.0003 g	Coal, fuel	38100000 g
Ground water	250 g	Uranium ore	6400 g
Quartz	2060 g	Unspec. biomass, DW, fuel	4330000 g
Clay	1420 g	Unspec. fuel	200 MJ
Manganese (Mn)	1760 g	Unspec. minerals	70800 g
Sodium chloride (NaCl)	33800 g	Unspec. resources	1530 g
Natural gas, fuel	14600000 g	Unspec. water	16900000 g
Natural gas, raw materials	6030 g	Zinc (Zn)	17400 g

3.3 Impact assessment

The impact assessment, based on the above inventory, is done according to the EDIP method [2,3]. The impact assessment calculations are fully computerised by the prototype EDIP LCA software, and will not be discussed.

4 Results

Fig. 5 and 6 show the total environmental load profile and the total stock depletion profile, respectively. The results are shown for one year of the product's 20-year life time. The environmental load profile states the potential environmental load from the entire ABB EU 2000 life cycle process system in terms of the unit milli person equivalent targeted (mPET), which is the unit for the normalised and weighted (prioritised) potential environmental impact, weighted according to reduction targets for the year 2000. The stock depletion profile states the total stock depletion from the entire ABB EU 2000 life cycle process system, i.e. including stock used for the product and help materials as well as energy carriers used to generate the energy (power, heat etc.) for the whole process system. The unit of stock depletion is the milli person reserve. One person reserve is the allotment of that stock to each global citizen and all of her/his descendants.

Fig. 5 and 6 show further the share of the use life cycle stage in the total environmental load and in the total stock depletion. It is evident that the use stage energy consumption is responsible for the vast majority of most of the effects on the external environment. This shows the typical picture for active products. These effects are all due to the production and particularly the burning of fossil fuel, or from the production of electricity by nuclear fission (radioactive waste).

Exempt from this are the contributions to the effect ozone depletion and the eco-toxicity effects. The somewhat critical contribution to ozone depletion comes from leaks of CFCs and HCFCs from cooling systems for manufacturing equipment. The contributions to eco-toxicity appear to come from virgin steel production, but the sizes of the potential

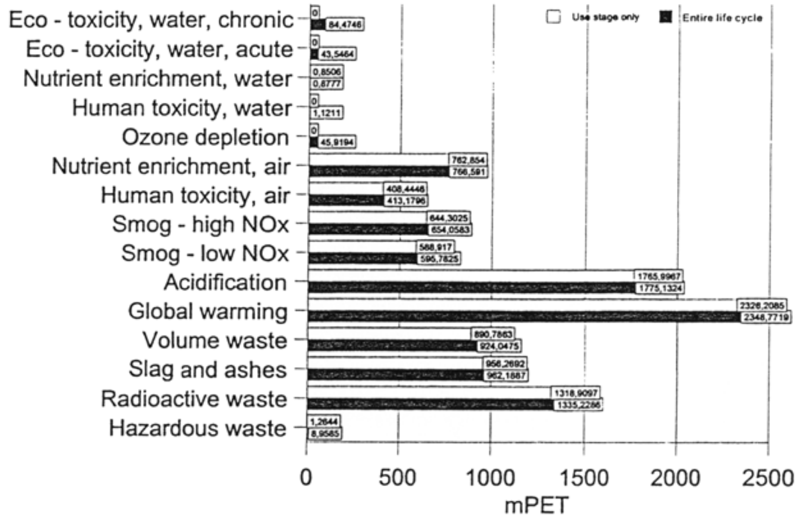

Fig. 5: The total weighted (prioritised) environmental profile for the ABB EU 2000 air handling unit

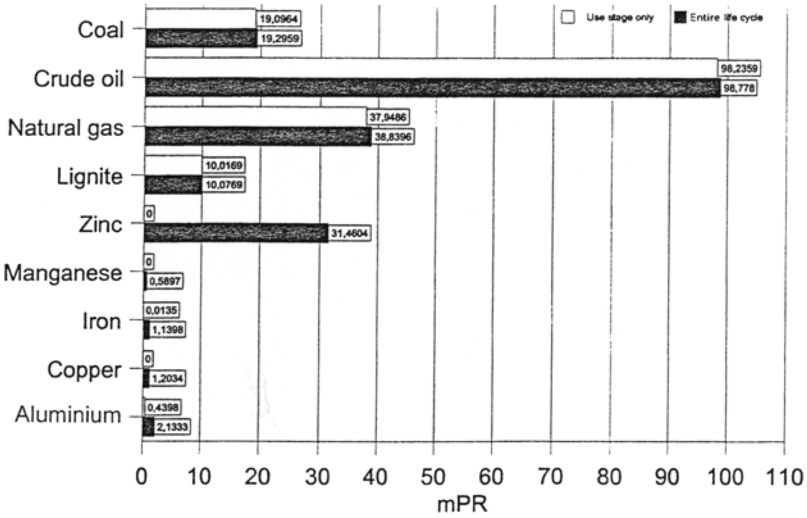

Fig. 6: The total stock depletion profile for the ABB EU 2000 air handling unit

impacts are ambiguous, due to lack of clarity about metal emission forms.

The part of the overall potential environmental impact that comes from the actual manufacturing at ABB Ventilation Products, ABB Coiltech and ABB Motors is quite small, apart of course from the ozone depletion contribution.

The stock depletion profile is for one year of the 20-year life time of the product. The use stage contribution is shown, and it clearly appears that most of the overall stock depletion indeed comes from the use life cycle stage, and is the consumption of the energy carriers crude oil, natural gas, lignite and coal. The consumption of iron, copper, manganese and aluminium is quite small, whereas the consumption of zinc stock is relatively high. Zinc is used for galvanisation, and although the thickness is a few microns, the total consumption amounts to kilograms. All other metals are assumed fully recovered in the present disposal/recycling scenario, whereas zinc is not assumed to be recovered at all. This may not be entirely true, as some steel smelters do recover some of the zinc as filter dust. But even though say 50% of the zinc was recovered, zinc stock depletion would still be quite high, as zinc is an extremely scarce stock. Further, quite a lot of zinc is lost to corrosion during the product's use-life.

The environmental load profile and the stock depletion profile are broken down according to rough sections of the product, namely parts 1-6, air cooler/heater and motors, in **Fig. 7** and 8, respectively.

It is once more quite clear from Fig. 7 that the active parts of the product account for most of the total potential environmental impact. This goes specifically for the motors, be-

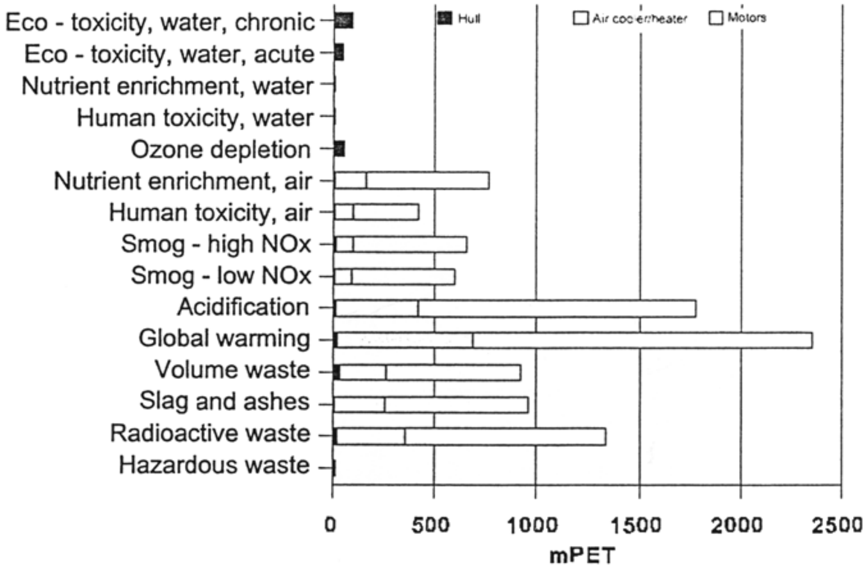

Fig. 7: The environmental impact profile, divided on major components of the product, where the hull is parts 1-6

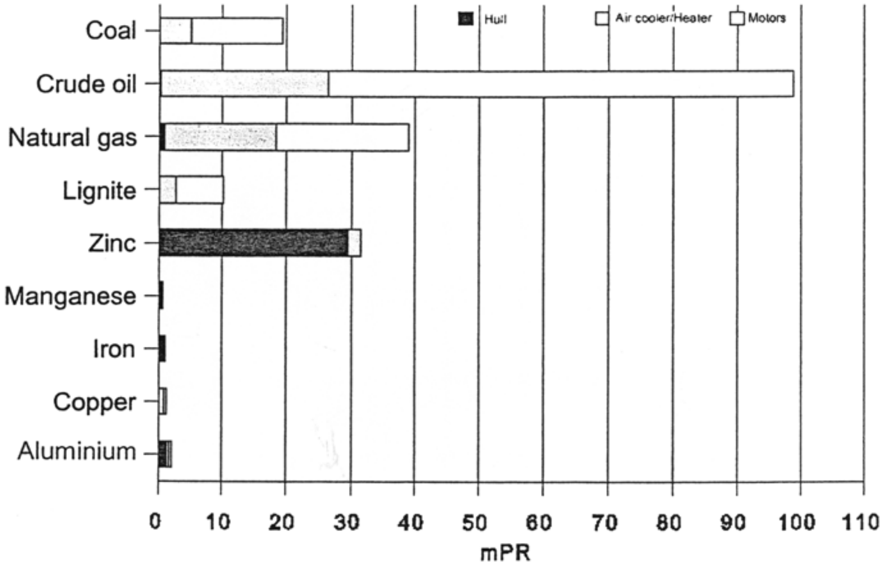

Fig. 8: The stock depletion profile, divided on major components of the product, where parts 1-6 represent the hull

ing the most active parts of the product. Although parts 1-6, etc. are the major part of the product weight wise, they do not account for major contributions to the energy-related environmental effects, but do account for the possible eco-toxicity impact towards water eco-systems as well as the ozone depletion potential.

Turning to Fig. 7, one major conclusion is that the energy carrier stock depletion is almost solely connected to the active parts of the product, which is only logical and quite typical. Zinc stock depletion is obviously connected to parts 1-6 to a large proportion, and the air cooler/heater to a small proportion, because these parts are made largely of galvanised steel sheets, with 20 microns of zinc on both sides of the sheets. Copper stock depletion is firstly not critical, due to the large degree of recycling in the present disassembly-based recycling scenario, and secondly comes mostly from the air cooler/heater units and, thus, not from the motors. A non-disassembly-based recycling scenario would lead to much larger depletion, particularly of copper and aluminium stock, due to the lower recovery efficiency of a shredder-based recycling scenario for instance.

5 Summary of the Results

The present study is on a screening level, because particularly the manufacturing life cycle stage and to some extent the disposal/recycling life cycle stage have been modelled somewhat crudely. Major conclusions, however, can be drawn from such a study, even though the exactness of the baseline data is not perfect.

The major results are:

- The majority of the total environmental load is associated with the fact that the product is a highly active product, using much energy to run. It is quite clear from the figures above that the energy related environmental effects account for most of the overall environmental impact.
- One exception to the above is the contributions to acute and chronic waterborne eco-toxicity, which largely come from virgin steel production. It must, however, be stated that what is measured is an impact *potential* and, particularly in this case where the effect potentials come from the emission of iron, it is doubtful whether the actual effect will be as high as the potential effect. (This is because some of the iron emitted may not appear as iron ions.)
- Another exception is the contribution to ozone depletion, which is relatively high, and comes from a loss of CFCs and HCFCs from the cooling of manufacturing equipment. An effort must be made to reduce this impact potential.
- Draws on metal stocks are not significant, mainly due to the choice of a disassembly-based recycling scenario. This goes for the interesting stock in this context, copper stock, as well.
- An exception to the low depletion of stock is the depletion of zinc stock, which is quite high. The zinc is used for galvanisation, some of it is lost to corrosion and the rest is not assumed recycled in the present recycling scenario.
- The vast majority of the overall depletion of stock is the depletion of stocks of the energy carriers crude oil, lignite, natural gas and coal. This is only naturally connected to the large energy consumption of the ABB EU 2000 air handling unit.

There are three major focus areas for improvement: Efficiency, substitution of CFC chemicals and the avoidance of galvanisation surface treatment.

The air handling unit is a highly active product, and most of the effects on the external environment and the high depletion of energy carrier stock are associated with this high level of activity. To significantly bring down the environmental and resource exchanges of the product means to effectively increase the efficiency of the product.There are a number of actions available to increase the efficiency of the air handling unit during operation:

- High efficiency and variable speed motors can be introduced in design and components with improved performance/pressure loss ratio can be developed
- The customer can optimise the selection of the unit size with regard to both purchase cost and operating cost
- Operational control systems can be introduced to run the air handling unit only when needed

Looking at the manufacturing of the components of the unit, there is a significant emission of CFCs and HCFCs from cooling of the manufacturing processes, leading to both ozone depletion and global warming impacts. Particularly the ozone depletion impact is critical, and it is highly recommended to look for substitutes to CFCs and HCFCs, with no ozone depletion impact and relatively low global warming impacts.

The final practice that should be looked into is the use of galvanisation for surface protection. This widely applied surface treatment process uses 50-60% of all zinc produced annually, and zinc is an extremely scarce stock with a supply horizon of less than 20 years. Furthermore, one has to remember that a fair amount of the zinc layer of the steel sheet surface is lost due to corrosion during use, which is why it is there in the first place. This fact, which was not treated in the model due to a lack of consistent data, contributes to toxicity effects, because zinc is also a heavy metal. Ways to proceed here are obviously to look for other surface treatment systems than galvanisation and/or other hull materials.

6 Discussion

The screening level LCA places itself between the full LCA approach and the streamlined LCA approach, in that it utilises the framework of the full LCA while requiring a much limited effort.. The inputs of the screening level LCA are considerably less comprehensive than those of the full LCA, however, allowing for an objective and fully quantitative approach compared with the streamlined LCA approach. The actual inputs needed to do a screening level LCA are:

- A bill of materials for the product.
- A description of how raw materials are shaped and pretreated before assembly of the product.
- A rough black box-like inventory for the manufacturing life cycle stage, based on last year's environmental reports for example.

- A distribution/export scenario.
- A use stage model.
- A rough disposal stage description, including information on what is recycled, deposited or incinerated.

What is not needed, saving considerable time, is a detailed inventory for the manufacturing stage and the actual up-to-date inventory data for all of the raw materials extraction and pre-manufacturing life cycle stages. The manufacturing stage is simply handled by putting a black box around the whole of the manufacturing site and allocating inputs and outputs to the product at hand in a reasonable manner. This obviously produces some uncertainty about the data basis for handling of this life cycle stage, but in practice is it quite easy to pin-point where impacts come from in the manufacturing stage once the result of the screening study exists, and to sort out further if they are significantly linked to the product in focus. The handling of the pre-manufacturing stage relies to a large extent on available data in the LCA database. This data are not fully up-to-date, but will nevertheless reveal major improvement options. Most western companies can now deliver the needed inputs quite quickly, or they will be able to do so in a not so distant future.

There are two basic requirements, though, and that is the availability of a fairly comprehensive database in which energy mixes and pre-manufacturing data, etc. are stored, and the services of an LCA modelling and computation tool. These databases and tools are now on the market from several vendors.

The present study serves to illustrate that solid statements on major improvement potentials can still come out of a screening level study. The resulting profiles and breakdowns do indeed point to focus areas in the product.

7 Conclusion

As carried out in this study, the screening level LCA requires a relatively limited effort and has produced an account of the major focusing points or improvement potentials in the ABB EU 2000 air handling system. The assessment is quantitative and rests on a detailed, although not fully validated, data basis, and requires only a few working days to be performed, given that the producer is geared to supply the basic input information. This input information is much less comprehensive than that of a full LCA, and in terms of effort the screening level LCA places itself in between full, comprehensive LCA and streamlined LCA.

Most manufacturers will have the input information available in terms of existing documents, and having been through the exercise once, the next screening level LCA is easier to perform. The screening level LCA can also act as the first iteration of a full, comprehensive LCA

The result can be used for major initial steps forward in terms of product-wise ecological improvements, and does provide both focus and direction in the early stages of a company's life cycle engineering efforts. Once all the "low hanging fruit" has been picked, however, there is a need for a more solid and comprehensive approach, as for example the full LCA approach linked with comparative studies of the improvement potentials of existing and emerging technologies.

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Received: May 15th, 1998
Accepted: October 27th, 1999
Online Publication: November 19th, 1999

Books

Perspectives in Life Cycle Impact Assessment: A Structured Approach to Combine Models of the Technosphere, Ecosphere and Valuesphere

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Author: Patrick Hofstetter

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Publisher: Kluwer Academic Publishers, Boston; November 1998; 504 pp., hardbound; NLG 360.00 / USD 159.00 / GBP 108.25;
ISBN 0-7923-8377-X

This book describes the relationship between subjective and objective elements in Life Cycle Impact Assessment. It suggests a new framework which will allow people to master two of the major problems associated with LCA, the difficulty of separating subjective from objective elements and the tendency for impact assessment to record 'phantoms' rather than actual damages.

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This book presents a proposal for a second generation framework and method for Life Cycle Impact Assessment. Many of the suggested elements are either based on other tools for environmental analysis, e.g. risk assessment, or fit in well with tools and concepts such as industrial ecology, technology assessment, or environmental impact assessment. The research presented in this book goes beyond the scope of presently used methods for Life Cycle Assessment and may stimulate new developments in a variety of areas.

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This book appeals to persons from a wide range of scientific disciplines who are interested in learning more about Life Cycle Assessment. It is especially valuable to members of SETAC and to students and researchers in the fields of environmental impact assessment, risk assessment and industrial ecology