Evaluating Life Cycle Assessment (LCA) Methodology at AMD Saxony for Identifying Resource Conservation Priorities

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AMD Saxony - Fab 30

- AMD Saxony with AMD 's Fab 30 is located in Dresden, Germany
- First shipments of the AMD Athlon™ processor in June 2000.
- Currently manufacturing all AMD Athlon MP, and AMD Athlon XP processors in advanced technologies and high volume.
- Preparations for the production of 8th generation processors (codenamed Hammer) and AMD Opteron™ underway.
- First European wafer fab to use copper interconnect in its production processes
- Leading the production of SOI-based products with AMD’s upcoming eighth-generation of AMD Athlon™ and AMD Opteron™ microprocessors.

AMD Saxony

EHS at AMD Saxony

EHS factors were considered in major fab design decisions such as the use of the more energy-efficient SMIF manufacturing concept; the use of NF3 Remote Clean Technology to reduce PFC emissions; and the implementation of an environmentally friendly cogeneration power plant.

Besides having considered EHS factors already in the planning phase, AMD Saxony has EHS programs in place, e.g.:

- To manage and minimize waste streams;
- To monitor and minimize emissions into air and water ;
- To minimize and monitor workplace exposures to hazardous substances;
- To review chemicals in regards to their EHS properties prior to their use in manufacturing
- To conserve resources and reduce pollutions.

AMD Saxony is an ISO 14001 certified site.

Fab 30 Chronology

AMD

09/02 **2000 Employees**

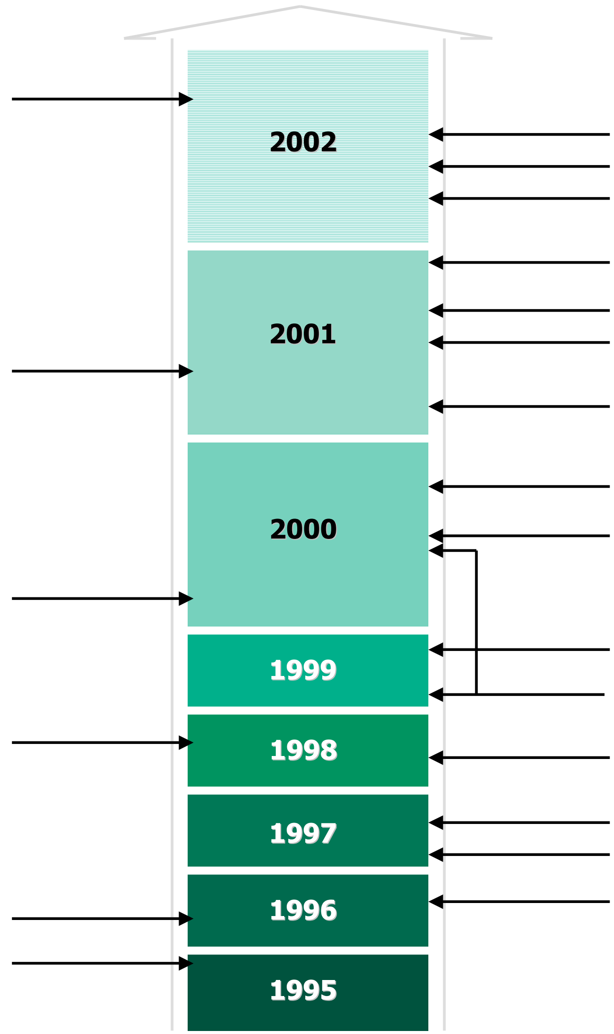
03/01 **1500 Employees**

02/00 **1000 Employees**

10/98 **500 Employees**

04/96 **1. Employee**

12/95 **Investment announced**



07/02 **Topping off second cleanroom extension**
06/02 **Cornerstone for AMTC**
03/02 **First shipment of 0.13µ CPUs**

12/01 **20. Mio CPU shipped / ramp-up concluded**

09/01 **New office & lab building complete**
07/01 **10. Mio processor shipped**

03/01 **Completion of first clean room extension**

09/00 **1. Mio processors shipped**

06/00 **First commercial shipment of 0.18µ CPUs**

10/99 **Grand opening**

01/99 – 05/00 **Technology qualifications**

05/98 **Clean room ready for equipment**

09/97 **Topping off**
05/97 **Cornerstone Ceremony**

10/96 **1. Groundbreaking**

What Is Life Cycle Analysis (LCA) ?

AMD

Definition

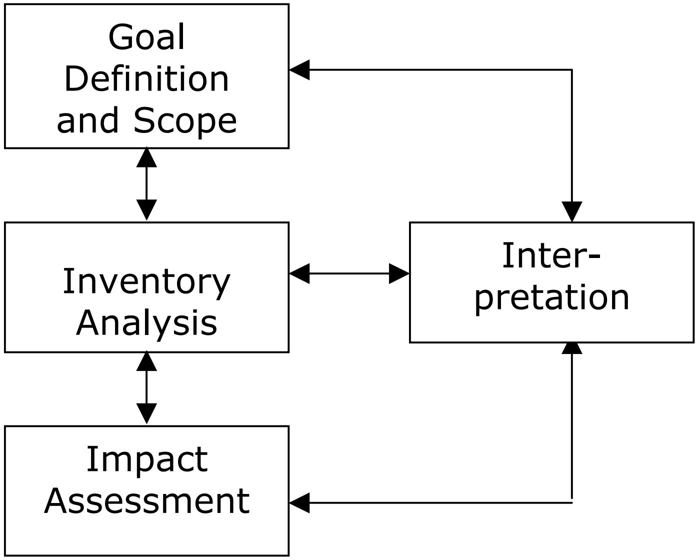
Life Cycle Analysis (LCA) is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service along their whole life cycle by:

- compiling an inventory of relevant energy and material inputs and environmental releases;
- evaluating the potential environmental impacts associated with identified inputs and releases;
- interpreting the results of the inventory and impact assessment in relation to the objectives of the study.

According to ISO 14040

Stages of an LCA

- ***Goal Definition and Scoping*** – **Define** and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.
- ***Inventory Analysis*** – **Identify and quantify** energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, wastewater discharge).
- ***Impact Assessment*** - **Assess** the human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.
- ***Interpretation*** - **Evaluate** the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results.



According to ISO 14040

Definition of Goal and Scope

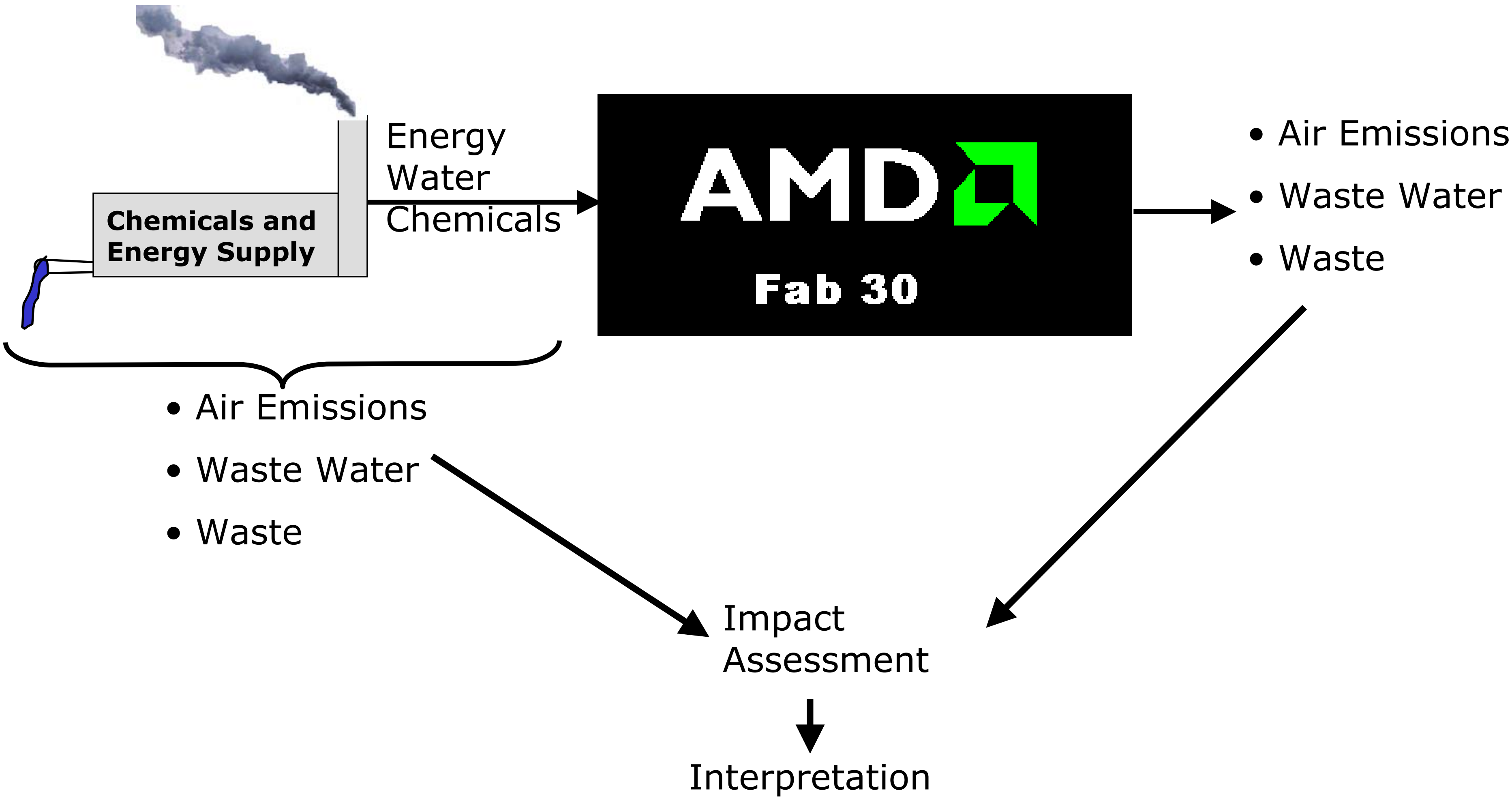
Goal

- Identify priorities for resource conservation at AMD Saxony
- Test applicability of LCA in regards to analyzing semiconductor manufacturing, identify gaps and shortcomings

Scope

- System consists of all major support and production processes at AMD Saxony.
- All energy and material flows surpassing the system boundaries in 2001 were quantified.
- Life cycle inventories and environmental impact potentials of the supply chains of energy and major chemicals (coverage of > 99% of input mass flow) were included.

Scope of LCA at AMD Saxony



Impact Categories for Impact Assessment

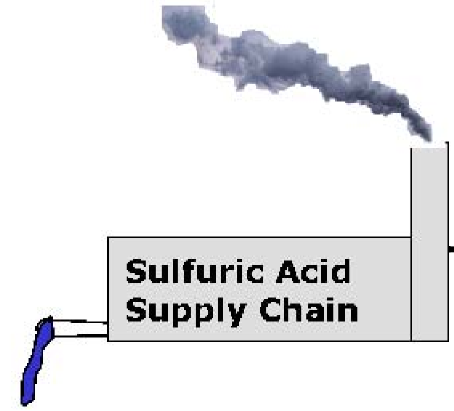
Eight impact categories were chosen, which are most common for quantifying environmental impact potentials in LCAs.

Values for impact characterisation factors were taken from a database provided by University of Leiden, Netherlands.

http://www.leidenuniv.nl/interfac/cml/ssp/projects/lca2/charac.html

Global Warming Potential (GWP)	→ CO_2-equivalent
Ozone Layer Depletion Potential (ODP)	→CFC-11-equivalent
Acidification Potential (AP)	→ SO_2-equivalent
Eutrophication Potential (EP)	→ PO_4^{3-}-equivalent
Photochemical Oxidation Potential (PCOP)	→ ethylen-equivalent
Human Toxicity Potential (HTP)	→ 1,4-dichlorobenzene-equivalent
Freshwater Aquatic Ecotoxicity Potential	→ 1,4-dichlorobenzene-equivalent
Terrestrial Ecotoxicity Potential (TETP)	→ 1,4-dichlorobenzene-equivalent

Allocation of Impacts to Resources Consumed



100 kg
H_2SO_4

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- Air Emissions
- Waste Water
- Waste

- Air Emissions, e.g.
  0,6 kg SO_2
  23 kg CO_2
- Waste Water
- Waste

Impact Assessment

Acidification: 0,6 kg SO2 Equivalents

Human Toxixity: 9,6 kg 1,4-Dichlorobenzene Equivalents

Global Warming: 23 CO2 Equivalents

Input Streams and Supply Chains Considered (Examples)

Energy (Electricity, Heat, Cold)

Bulk gases (Nitrogen, Oxygen, Argon)

Acids (HCl, H_2SO_4, H_3PO_4, HF, CH_3COOH (*), Cr(+VI)03 (*))

Caustics $Ca(OH)_2$, NaOH, NH_4OH, KOH, H_2O_2 (*)

Solvents: IPA, Ethyl Lactate (*), NBA (N-Butylacetate) (*)

Data sources:

- Databases for life cycle inventories of selected materials and energies (e.g. Umweltbundesamt (German Federal Environmental Agency), data used in former studies from other databases)
- The asterisk (*) marks chemicals, where default datasets had to be used, since no specific datasets were available in available databases.

Output Streams Considered (Examples)

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Air Emissions
e.g. HF, HCl, Cl_2, NH_3, Solvents and PFCs

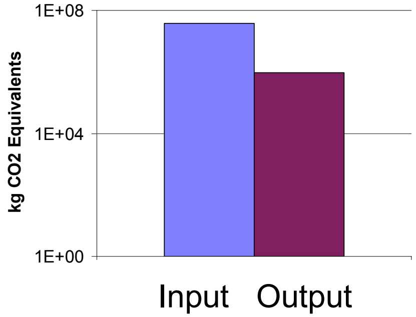
Waste Water
e.g. N, P, NH_4, NO_3, Cu, Sulfide, Sulphate

Waste
e.g. sludges, wood, paper, paperboard, scrap, plastic film (#)

Data sources:

- Output data were taken from site emission monitoring and waste database
- Life cycle inventories of the waste disposal chain were not included in the analysis since data were not available in a timely fashion (#).

Global Warming Potential



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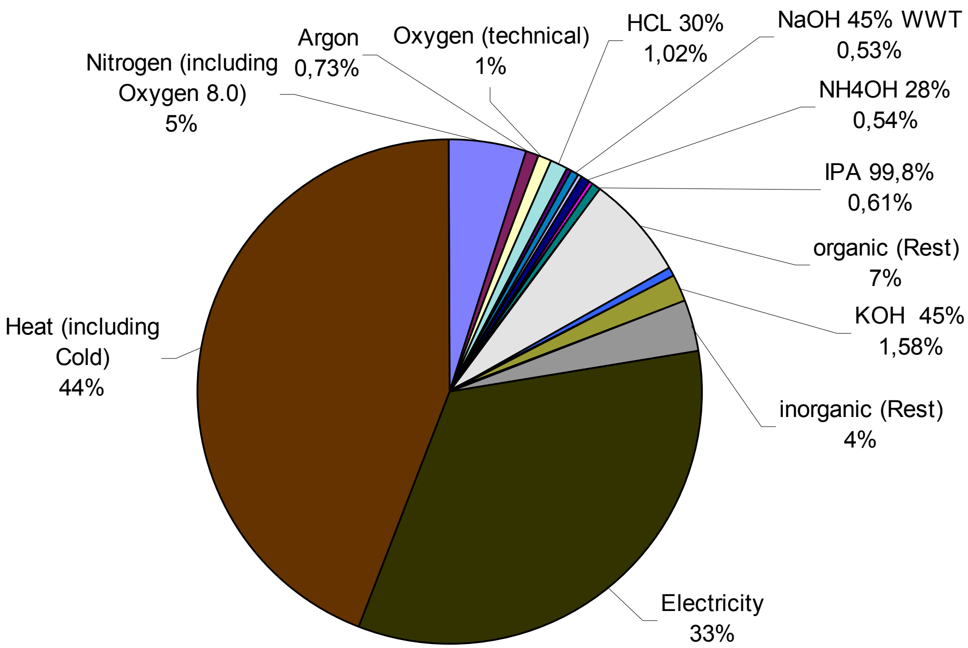

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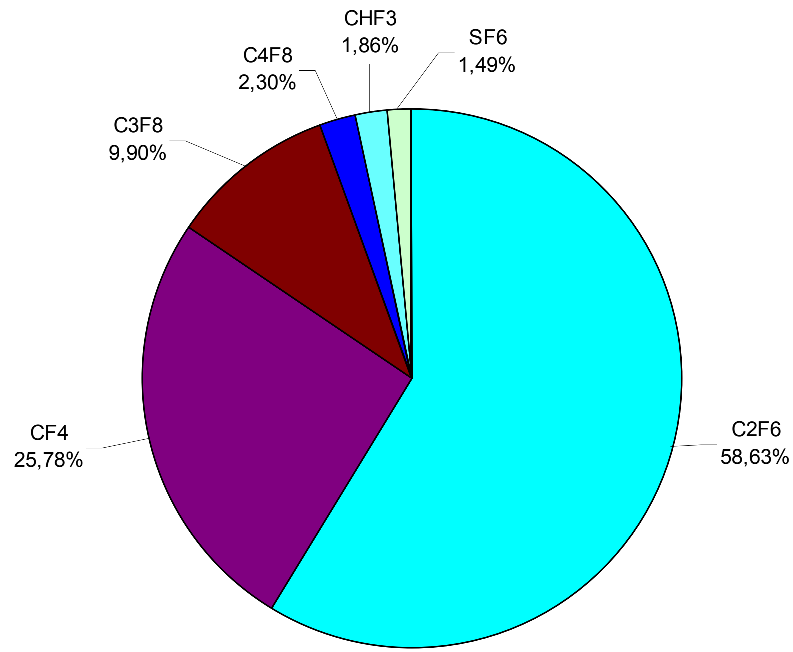

Ozone Layer Depletion Potential

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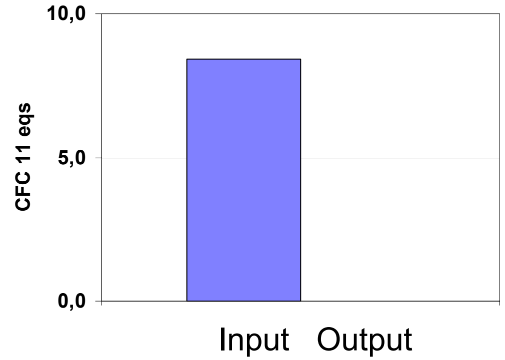

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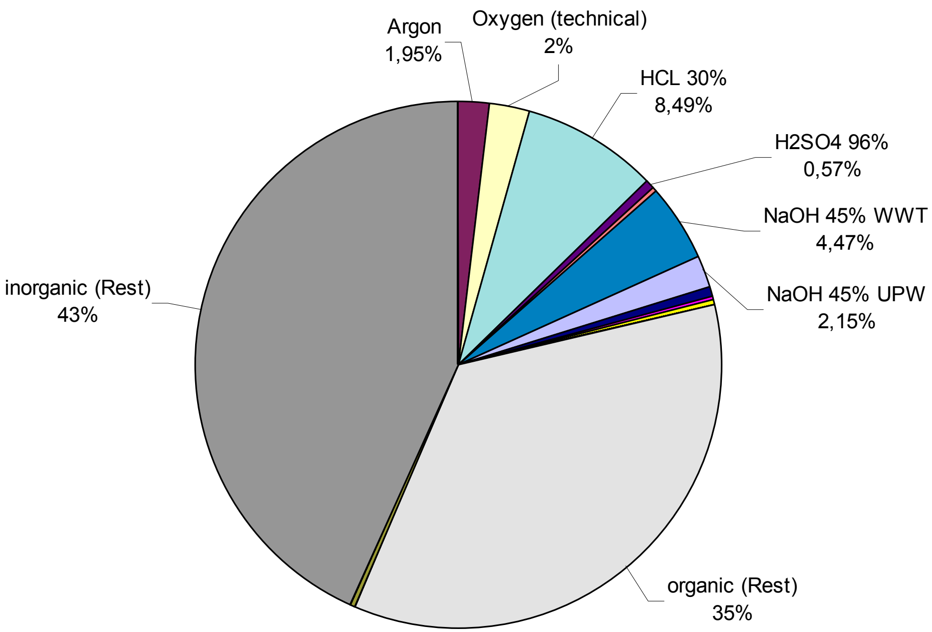
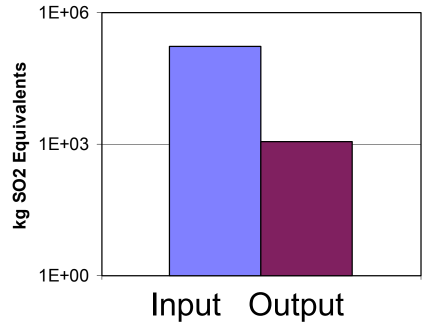


Output

No emission of ozone depleting substances

→Therefore no contribution to Ozone Layer Depletion Potential

Acidification Potential



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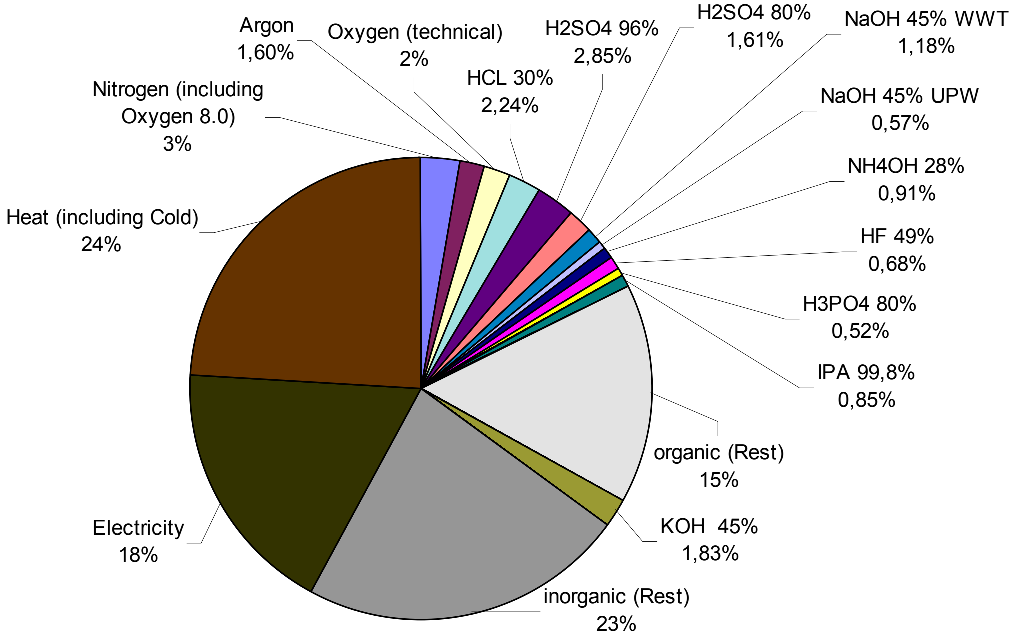

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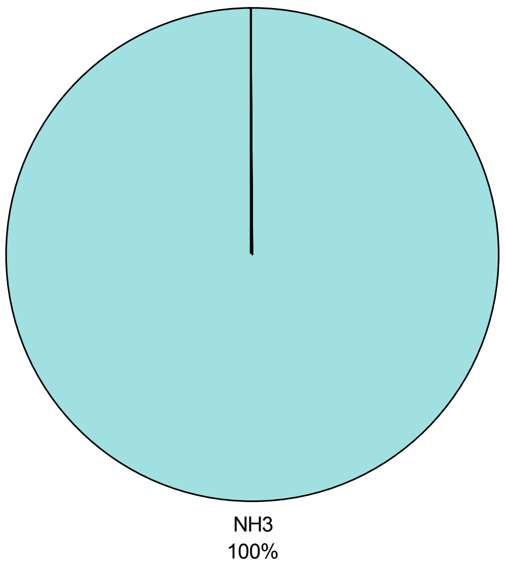
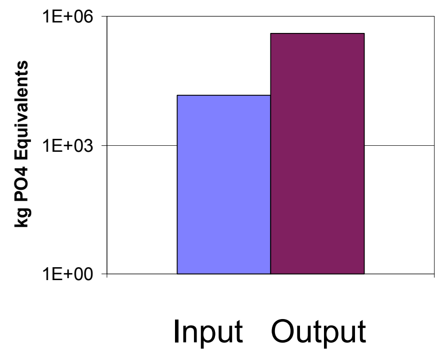


Eutrophication Potential



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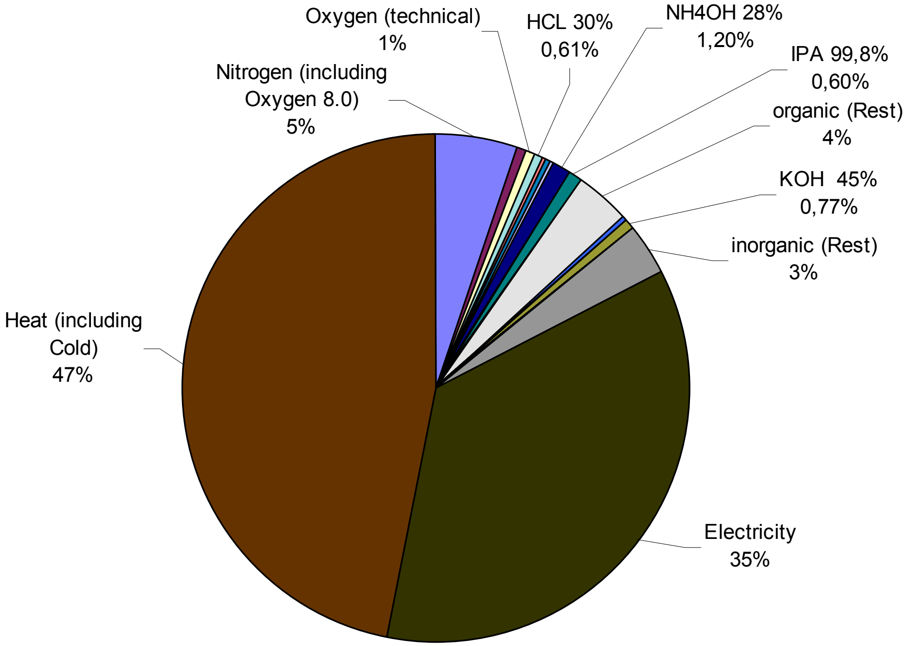

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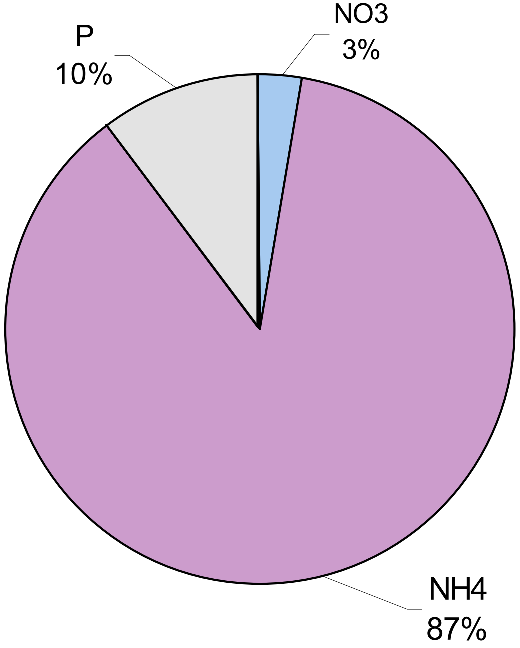
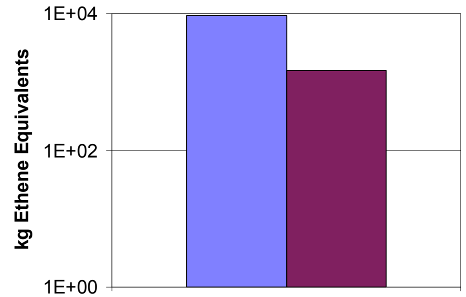


Photochemical Oxidation Potential



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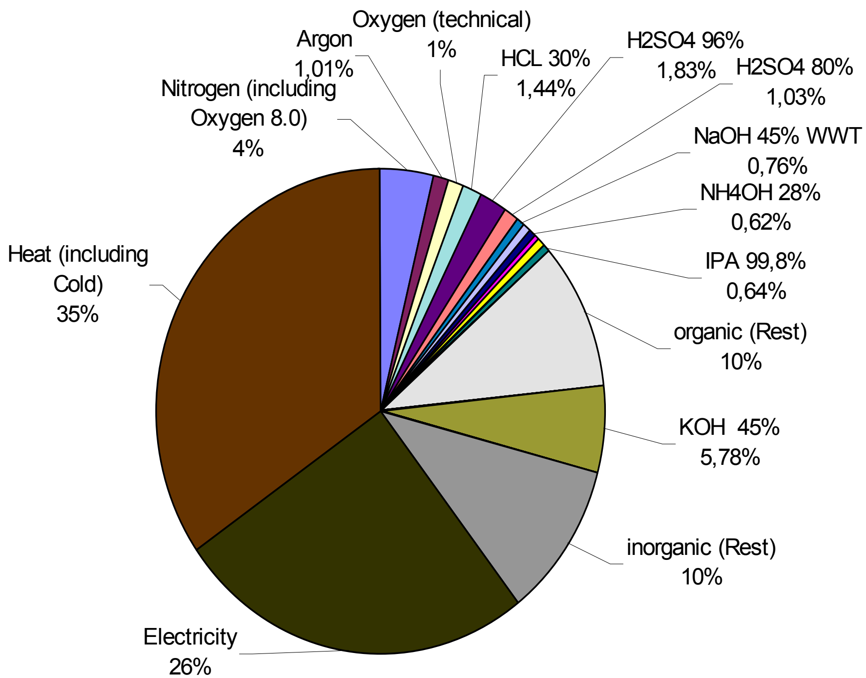

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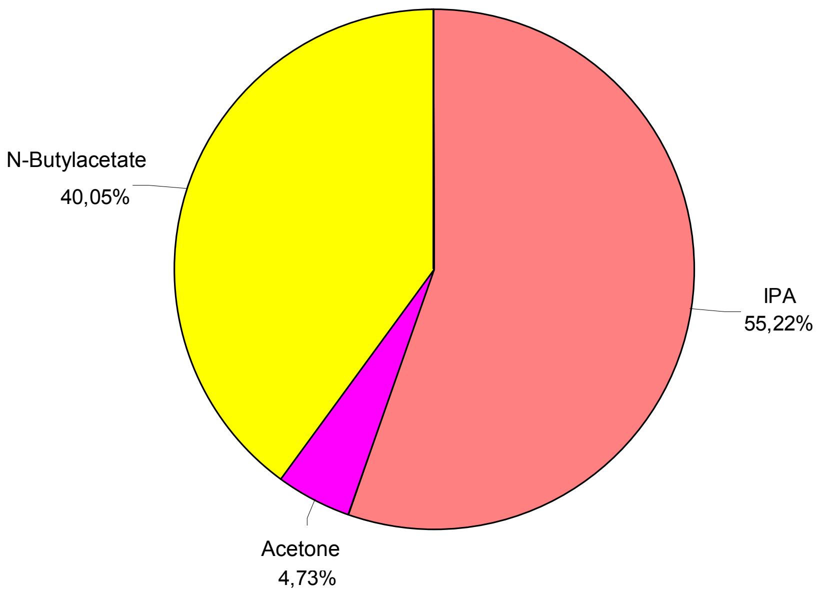
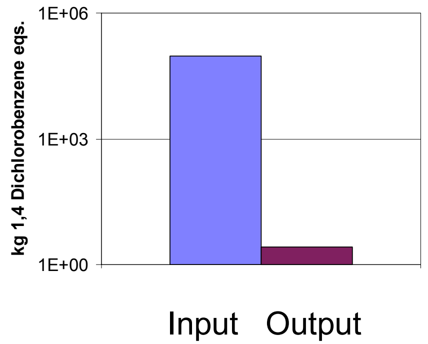


Human Toxicity Potential



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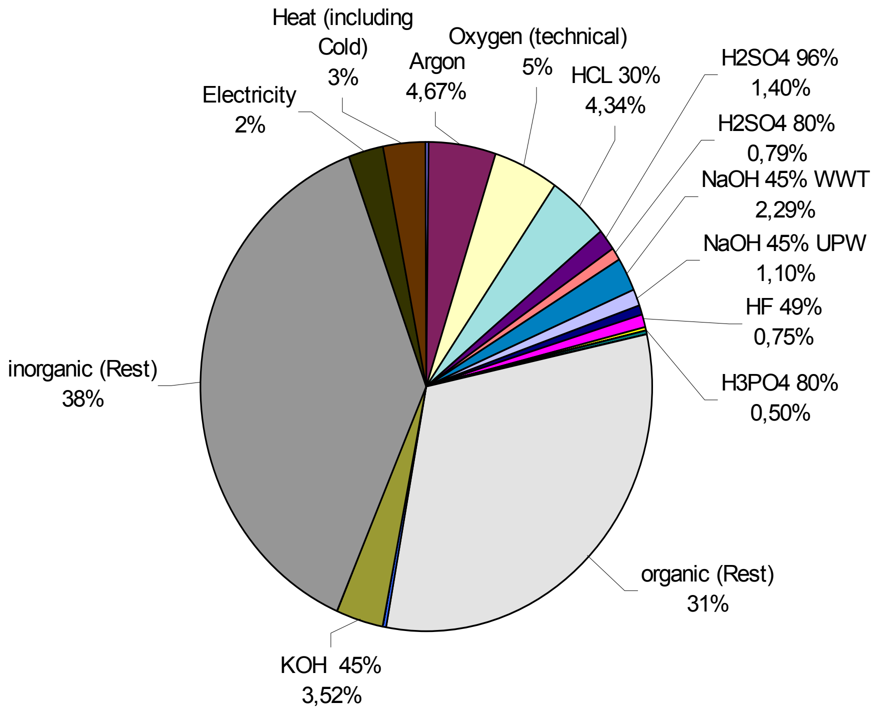

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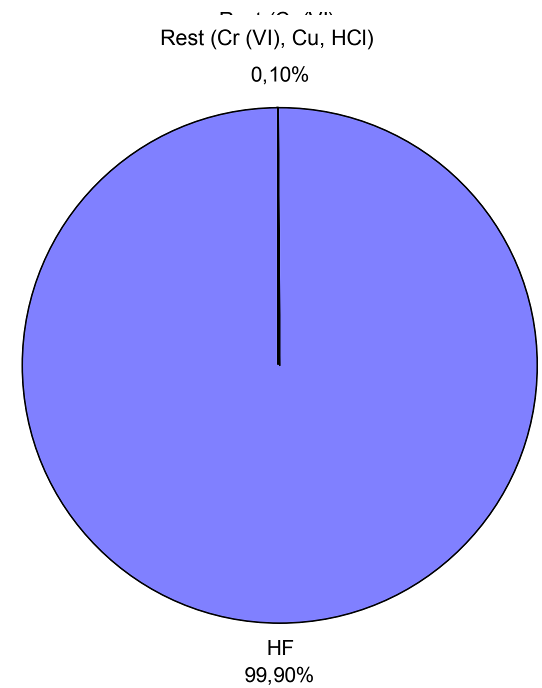
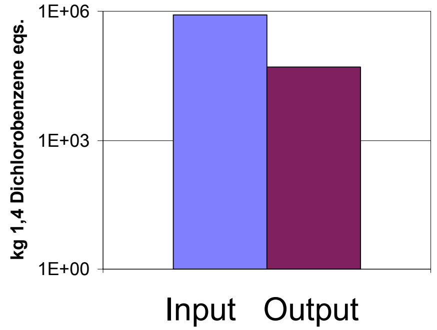


Freshwater Aquatic Ecotoxicity Potential



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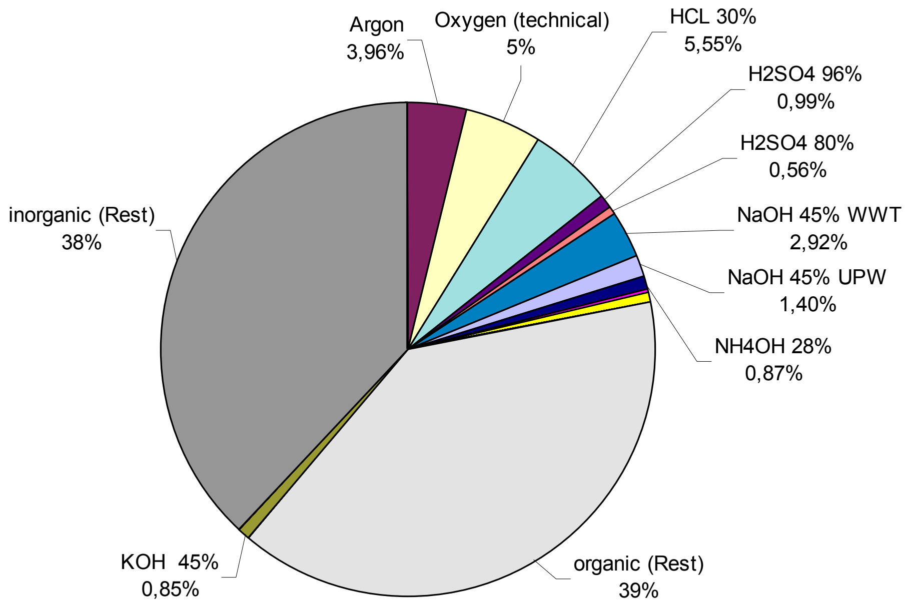
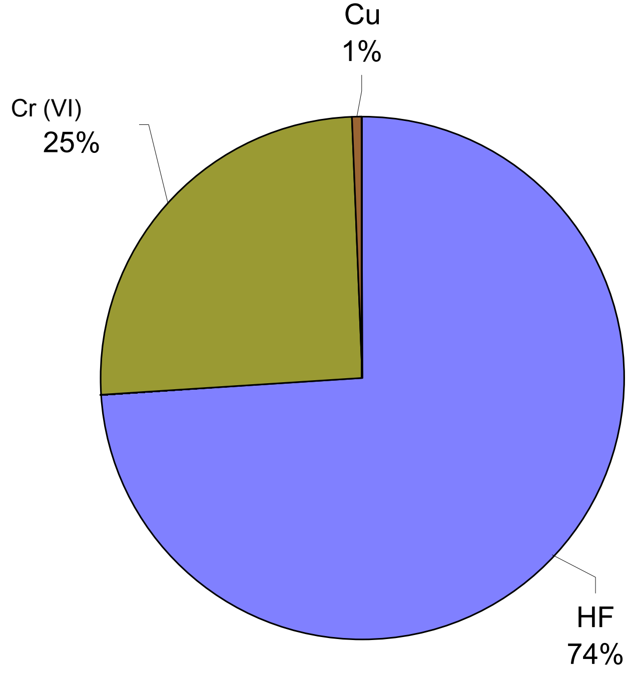
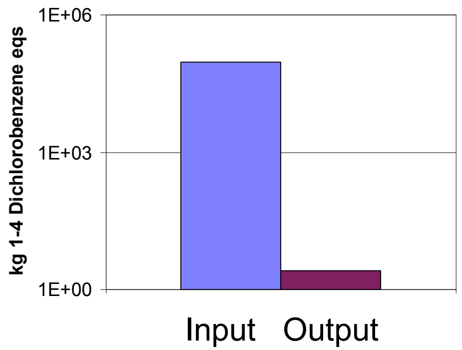
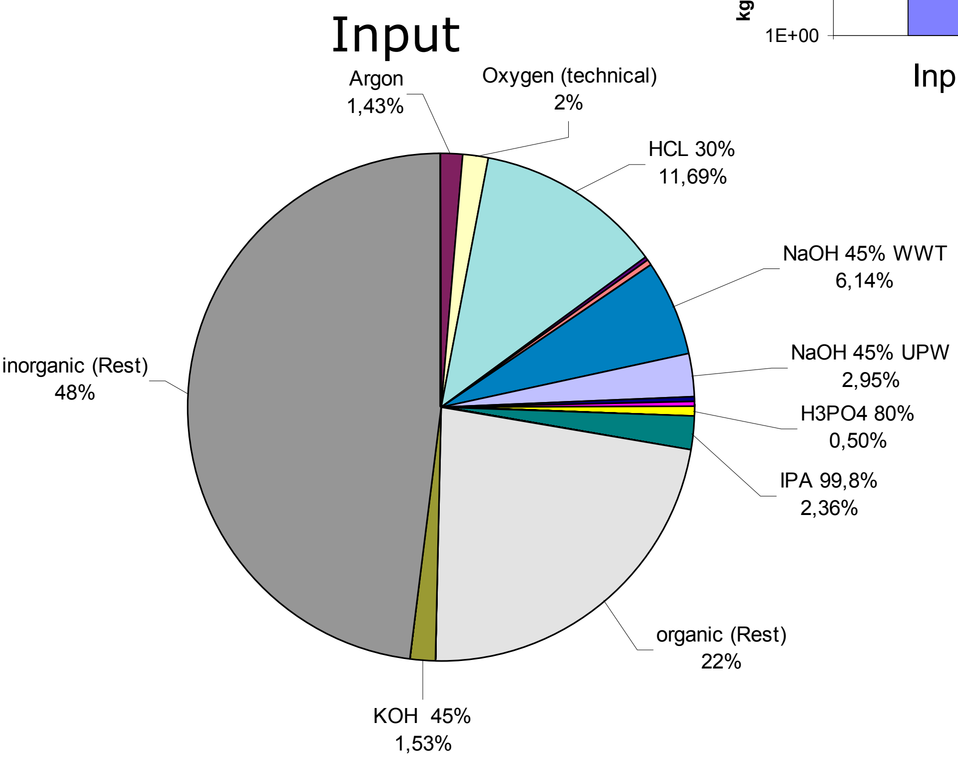
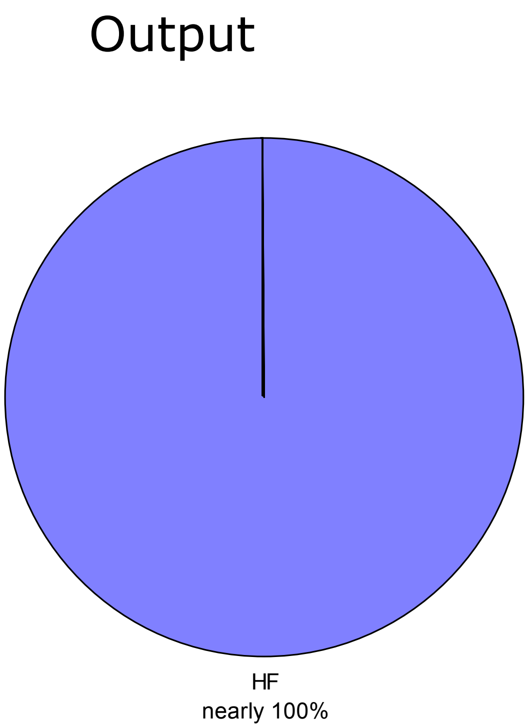




Terrestrial Ecotoxicity Potential







Interpretation: Priorities for Resource Conservation and Pollution Prevention

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- Priority input and output streams identified as the three biggest contributors in each impact category
- Chemicals for which default data sets were used were not included in the interpretation due to assumed data uncertainty

Impact Category	Input Stream	Output Stream
Global Warming	Heat, Electricity, N_2	C_2F_6, CF_4, C_3F_8
Ozone Layer Depletion	HCl, NaOH, O_2	no contribution
Acidification	Heat, Electricity, N_2	NH_3
Eutrophication	Heat, Electricity, N_2	NH_4, P, NO_3
Photochemical Oxidation	Heat, Electricity, N_2	IPA, NBA, Acetone
Human Toxicity	O_2, Ar, KOH	HF
Freshwater Aquatic Ecotoxicity	HCl, O2, Ar	Cu, Cr(VI), HF
Terrestrial Ecotoxicity	HCl, NaOH	HF

Conclusions

- In principle applicable for identifying environmental priorities for a whole semiconductor manufacturing site.
- Top down approach allows more focused further analysis of the processes where priority resources are consumed
- Very time consuming to set up a system to handle all necessary data
- Does not replace risk assessment: it only quantifies potential impacts, not actual risks!

Gaps and Future R&D

Gaps

No specific life cycle inventories available for many semiconductor specific chemicals (e.g. developers, slurries, solvents)

Use of default datasets for those chemicals leads to high uncertainty

Possible future R&D:

Availability of life cycle inventories of semiconductor specific chemicals would improve quality of this analysis.

A good starting point would be to obtain data of high volume semiconductor chemicals used throughout the industry:

- Developers (with main ingredient TMAH)
- Slurries (data for common ingredients)
- Solvents (Ethyl Lactate, N-Butylacetate (NBA)

References

ISO:
ISO 14040 - Environmental management - Life cycle assessment - Principles and framework, ISO June 1997

Umweltbundesamt (German Federal Environmental Agency):
„Prozessorientierte Basisdaten für Umweltmanagement-Instrumente (ProBas)"http://193.174.169.38/Probas/index.htm (German only)

Centre of Environmental Science Leiden University "Characterisation factors from the LCA Handbook"
http://www.leidenuniv.nl/interfac/cml/ssp/projects/lca2/charac.html

Matthias Dainz:
„Stoff- und Energieflussanalyse bei AMD Saxony", Praxisarbeit at AMD Saxony, July 2002

Silke Hermanns:
„Abschätzung von Art, Menge und Herkunft der Umweltbelastungen der Produktion von Halbleiterbauelementen"
TU Berlin, August 1997 Diploma thesis (German only)