INTRODUCING THE GEMIS LCA SOFTWARE FAMILY

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ABSTRACT

GEMIS (Global Emission Model for Integrated Systems) is a computerized life-cycle analysis model, LCA database, and cost-emission analysis system. GEMIS evaluates environmental impacts of energy, material and transport systems, i. e. air emissions (SO_2, NO_x, particulates, CO, NMVOC etc.), greenhouse gases (CO_2, CH_4, N_2O etc.), solid/liquid wastes, and land use. It can be used to analyze local, regional, national and global energy/material/transport systems, or any scope of sectoral or cross-sectoral sub-system (e.g., a plant, facility, or special life-cycle). Furthermore, GEMIS can determine the economic costs of scenario options.

Since 1987, Öko-Institut (Institute for Applied Ecology) in Germany developed GEMIS as a publicly available, free software and database. In 1990, an English version called TEMIS (**T**otal-**E**mission-**M**odel for **I**ntegrated **S**ystems) was developed for US-DOE, and in 1995, a similar tool called EM (**E**nvironmental **M**anual for Power Development) was developed for German GTZ, and the World Bank to extend the scope to developing countries. Since GEMIS 3.0, the model runs under Windows® on IBM-compatible PCs.

The GEMIS/EM database is the most relevant part of the model, offering data for more than 5,000 processes, and covering more than 30 countries. Currently, Öko-Institut works on an improved, **multi-language** version 4.0 which will be available in late 1999. Data from GEMIS will be available also in the Internet, and the future GEMIS 4.0 database will contain English summaries of all processes. Data export to ACCESS format, and linkage to EXCEL will be further new features of the upcoming new model release.

With GEMIS 4.0, all previous "daughter models" will be integrated into one single software which can be switched to other languages (including Help, and Online Documentation).

The GEMIS model family is used in OECD countries (Austria, France, Germany, Italy, Japan, Luxembourg, UK, USA), more than 20 developing countries (e.g., China, India, South Africa), and Central/Eastern Europe (Bulgaria, Czech Republic, Poland, Russia, Slovenia).

The software is *public domain* (i.e., free of charge), and updated regularly. More information can be found on the GEMIS websites [http://www.oeko.de/service/gemis (in German) http://www.oeko.de/service/temis and http://www.oeko.de/service/em].

KEYWORDS

GEMIS, TEMIS, EM, greenhouse-gas emissions, GHG modelling, life-cycle analysis, international database, cost-effectiveness, public domain software.

INTRODUCING THE GEMIS MODEL FAMILY

Since 1987, Öko-Institut (Institute for Applied Ecology) developed a computerized life-cycle tool called GEMIS (**G**esamt-**E**missions-**M**odell **I**ntegrierter **S**ysteme). It is a publicly available, cost-free software and database for life-cycle analysis used world-wide in a variety of applications.

In 1990, an English version called TEMIS (**T**otal-**E**mission-**M**odel for **I**ntegrated **S**ystems) was developed for US-DOE, and a preliminary US database was established. From 1991 to 1992, similar work was carried out for Italy, Turkey, and the UK, and used in ICLEI's Urban CO_2 Reduction Project.

In 1994, the so-called **EM** (**E**nvironmental **M**anual for Power Development) was developed for German GTZ and the World Bank to extend the scope of both the GEMIS model, and its database to developing countries. As part of the EM project, the model was converted from DOS to MS-Windows®.

With the current version 3.x (and the upcoming version 4.0), GEMIS runs only on 32-bit operating systems (i.e. Win9x, Win-NT 4.0), 16-bit-support is not longer available. With the new GEMIS 4.0, the model also changes its name: it will still be called GEMIS, but the acronym now stands for **G**lobal **E**mission **M**odel for **I**ntegrated **S**ystems.

GEMIS 4.0 is a multi-language software which can be switched from German to English (and back) – both for the model, and its database. Further language options (French, Spanish etc.) will be made available in the future.

KEY GEMIS FEATURES

 is a database system: It offers environmental and cost data for energy, material, and transport systems, including their life-cycles. The environmental data cover air emissions (SO_2, NO_x, particulates, CO, HCl, HF, H_2S, NH_3, NMVOC), greenhouse gases (CO_2, CH_4, N_2O, HFC, PFC, SF_6), liquid effluents (AOX, BOD, COD, N, P), solid wastes (ashes etc.), and land-use. The cost data concern investment, fixed annual, and variable cost, as well as externality factors for air emissions, and GHG. Further data are stored for "meta" information: comments and description, references, data quality indicators, location and statistical group.
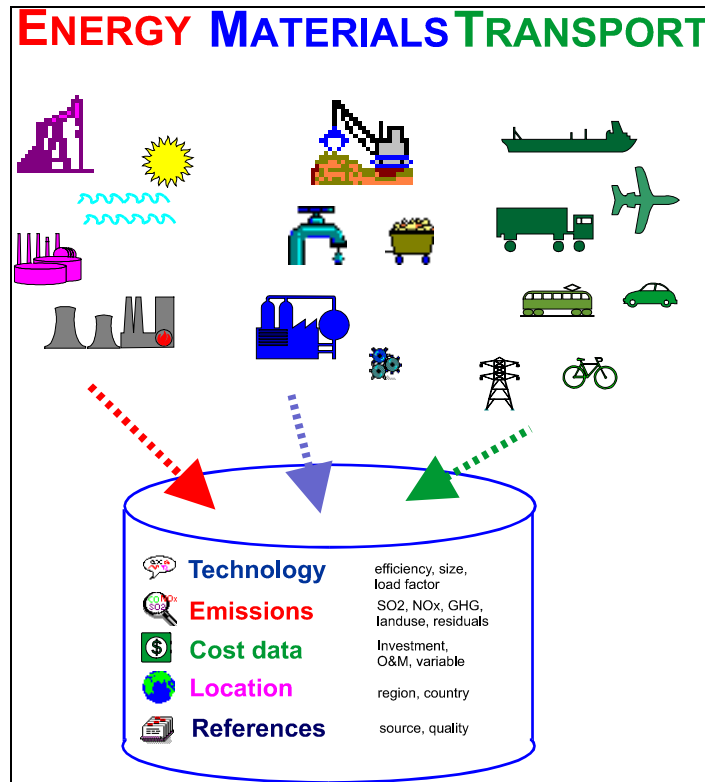
 is an analysis system: It determines full life-cycle impacts of energy, transport, and material technologies. In addition to the totals, GEMIS also gives the individual contributions of all processes to a calculated result (breakdown), and can determine results for selected system boundaries (e.g. a special location, in- or exclusion of material acquisition, crediting).
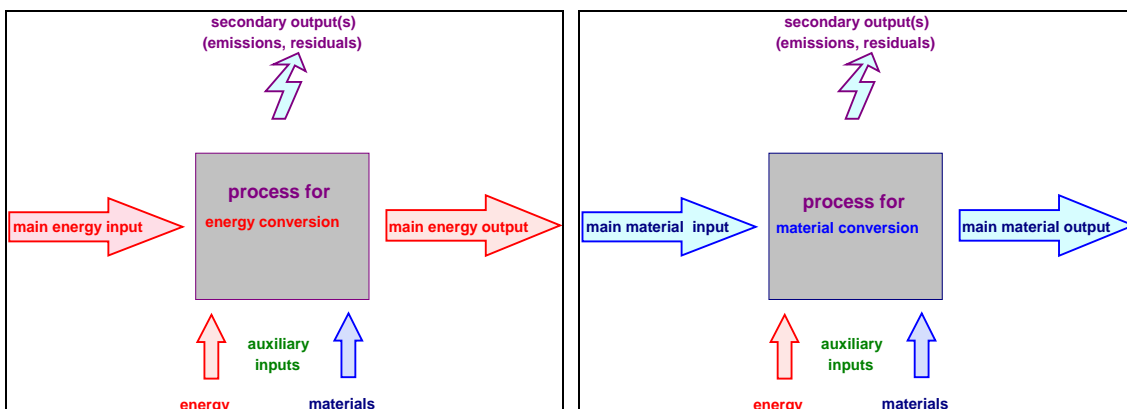
is an evaluation tool: It evaluates deviations from multiple objectives (trade-offs), e.g., costs vs. emissions, or emissions vs. land use. It further calculates CO_2 and SO_2 equivalents, and the total resource use (cumulative energy and material demands). Because of the modular approach of the database ("unit" processes), the sensitivity of any result can be determined quickly by copying original data, and adjusting key parameters – within seconds, GEMIS then calculates the new results which can be compare immediately with the original data.

The most prominent part of GEMIS is the database:

The database stores information on "unit" processes reflecting activities for which efficiency, emissions etc. can be measured, calculated, or derived from other sources (e.g. standards). No formal distinction is made between energy and material flows - all are interlinked, and have the same structure:
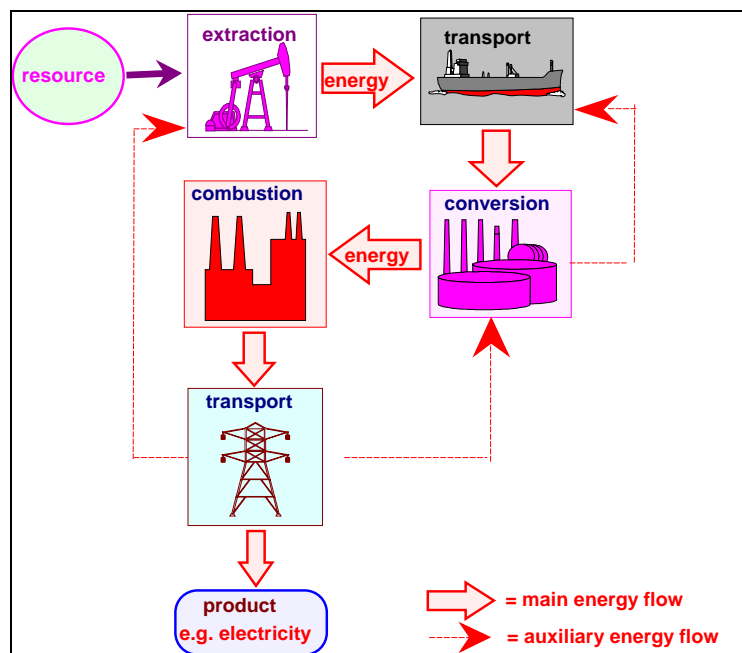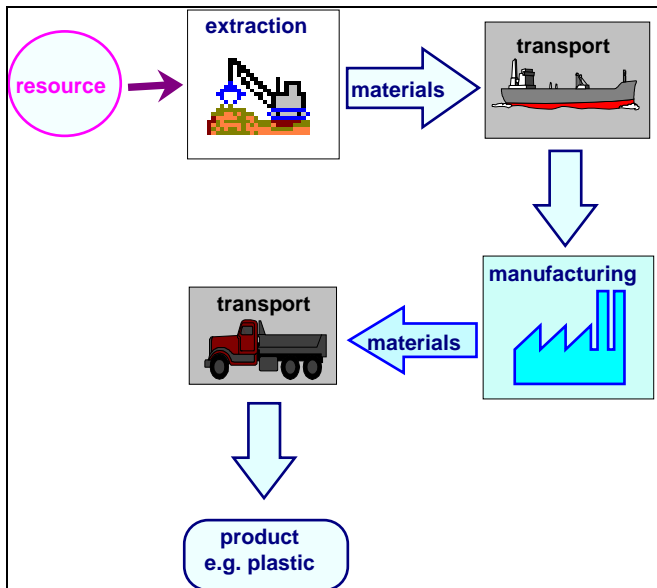
There are more than 2,000 "unit" processes in the GEMIS database, and more than 2,500 in the EM database. In GEMIS 4.0, these two will be merged into one integrated version, and some additional new technologies (e.g. fuel cells) will be included. The GEMIS 4.0 database will offer approx. 5,000 process data records for more than 30 countries.
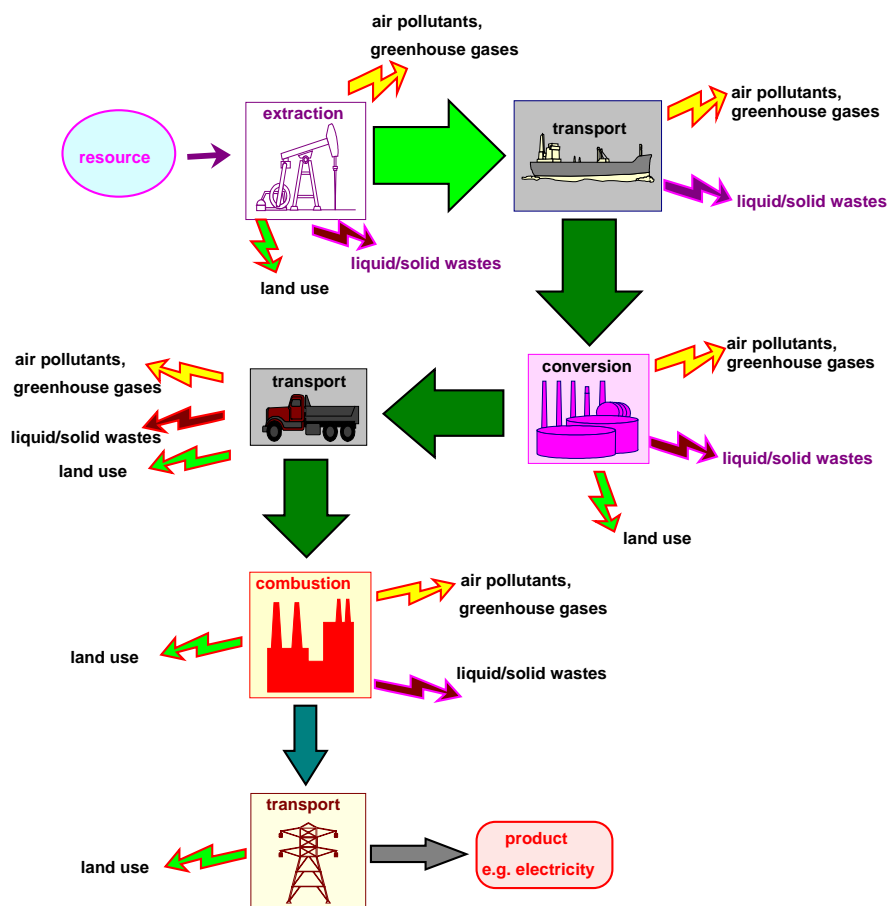
DATA SOURCES

The GEMIS technology data come from industry sources, life-cycle studies, and national or UN statistics, and have been cross-checked with other studies. Emission data come from GHG inventories, technology assessment studies, operation experiences, specs of manufacturers, and environmental standards, based on German, EU, US EPA/DOE, and IEA/OECD sources. For developing country data, case studies and applications have been carried out, and national as well as utility data were the bases for the country datasets.

The GEMIS database comes with pre-defined life-cycles – both for energy, and materials (including transport). The principle of life-cycles is to logically link "unit" processes to each other, so that from the individual process data, the overall flow per unit of output ("service") can be calculated.

The energy and material flows (and the associated transport needs) can then be used to calculate the emissions which occur along the life-cycles:
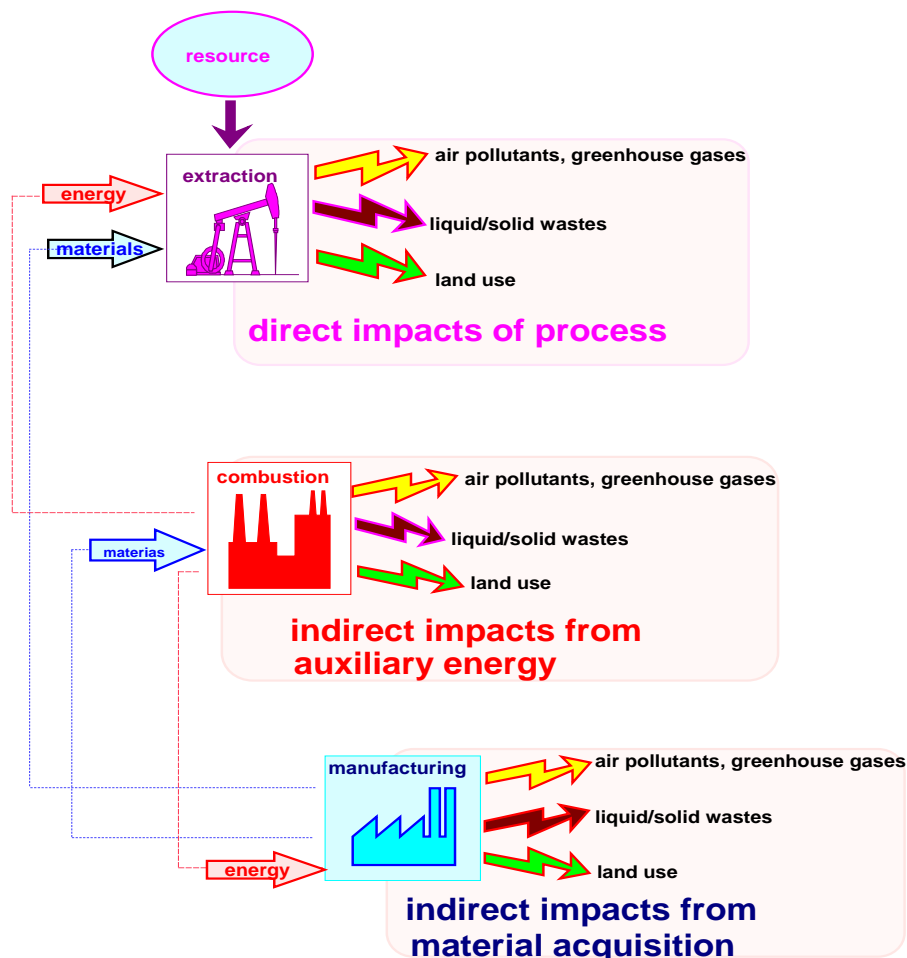

For this, the turnover in each process "box" is multiplied with emission data, and the sum of all processes involved is then calculated by GEMIS.

To fully embrace the cradle-to-grave logic, not just the operation ("life") of energy, material, and transport systems must be considered, but also their "births" and "deaths": It takes materials to construct an energy facility, and similarly, transport systems must be built before they can deliver fuels or other freight.

So, in full life-cycle analysis, there are three levels of possible environmental impacts:

direct impacts from operation, indirect impacts from auxiliaries, and indirect impacts from materials needed to built the process(es).

This is shown schematically in the following figure:

Typical life-cycles also cross national borders: Energy carriers and materials are imported from other countries, and products manufactured domestically are exported to other nations (e.g. hardware, food). Therefore, the GEMIS database traces the origins of energy and materials (resources extraction) from more than 20 countries, and using various transport systems, delivers energy carriers and materials to other countries.

KEY FEATURES OF THE GEMIS 3.x/4.0 VERSION

The upgrade of GEMIS 3 to an e**x**tended version comprises three main features:

- direct dynamic linking of GEMIS 3.x scenarios to external spreadsheets (EXCEL format)

- direct export of the GEMIS 3.x database into ACCESS and HTML format

- user-controlled scope of life-cycle computations (variable system boundaries)

The **dynamic linking** of GEMIS 3.x scenarios is the most relevant feature for the future extended applications of the software in the area of local/regional greenhouse-gas mitigation analysis and policy formulation. One can directly import scenario data from other models using EXCEL spreadsheets, and also export GEMIS scenarios into the same format.

The **database export** of GEMIS 4.0 to MS-ACCESS® allows to fully use all information **outside** of the model – also facilitating data documentation, and reporting. The new feature to directly create HTML pages (including indexes) makes it easier to share information with other users – with GEMIS 4.0, a full-scale online database with be available on the project website, including all information stored in all country datasets.

The **user-controlled scope** of the life-cycle computation allows to quickly adjust the system boundaries – factoring in the materials used for construction, allocating credits for multi-output processes (e.g. cogeneration), and considering transports in life-cycles: all these factors of the computational scope can now be selected with a few mouse clicks.

Using this new feature, one can use the software in a territorial "accounting" mode, and switch back to full life-cycle analysis without changing the database. This is the bridge to other databases (e.g., GHG inventory studies, national emission reporting etc.), and broadens significantly the application options for GEMIS.

Further upgrades are ISIC/NACE-compatible definitions of process groups which allow to include „top-down" data form other databases, and to aggregate results into statistical groups for the comparison of GEMIS results with „top-down" models.

This new GEMIS feature can also be used to monitor/verify voluntary GHG emission reduction agreements of (economic) actors.

USERS AND APPLICATIONS OF GEMIS

Since the release of GEMIS 3.0 and the EM 1.0 in 1995, more than 2,000 users have down-loaded the programmes from the internet websites, or received copies on CDROM.
Users and applications of the GEMIS model family cover a broad range of countries:

- **Western Europe**: Austria, France, Germany, Italy, Luxembourg, Netherlands, UK (with a few users in Belgium, Denmark, Finland, Portugal, and Sweden)

- **Central/Eastern Europe**: Croatia, Czech Republic, Poland, Romania, Russia, and Slovenia

- **Africa**: Morocco, and most SADC countries (Botswana, Namibia, South Africa, Tanzania, Zambia, Zimbabwe)

- **Asia**: China, India, Indonesia, Philippines, Vietnam.

- **other**: Fiji, Japan, USA

On the German GEMIS an the English TEMIS and EM websites (see below), access to both the models and country databases, as well as model documentation and help documents is available. Furthermore, reports from applications can be downloaded, and user directories help to find partners or references around the world.

ACCESS TO GEMIS

The use of the GEMIS model family is free of charge –installation files are available via the Internet at **http://www.gemis.de**

The „Environmental Manual for Power Development" (EM) database is integrated in GEMIS since version 4.0, but a separate installation package & database is available upon request.

The GEMIS website is continuously updated and extended, and offer news on upgrades, database extensions, and GEMIS applications.

PERSPECTIVES OF GEMIS APPLICATIONS

Currently, we are working on GEMIS applications for the so-called "clean development mechanism" (CDM) in developing countries, and the database extensions to agricultural and food processes. Work is also under way to use GEMIS for Local Agenda 21 activities (see the example of Marrakech 21 for Morocco).

In the future, we expect to establish a full EU database, and to work with partners on additional country data for Latin America.

ACKNOWLEDGEMENT