

**User's Manual**

***EcoSense 2.0***



## Acknowledgment

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The windrose trajectory model which is implemented in *EcoSense* is a HTM-like atmospheric model (HTM = Harwell Trajectory Model, developed by Derwent and co-workers at AEA Technology, Harwell Laboratory, UK). It is configured to resemble results of a 1991 FORTRAN version of HTM, but program design and implementation are quite different from the FORTRAN HTM, and it contains no code written by AEA Technology. Dr. Colin Johnson, at that time (1993) AEA Technology, encouraged the use of the model by various ExternE teams, provided the 1991 FORTRAN version of the HTM, literature on the model, and a one-week training on concepts and application of HTM at Harwell Laboratory. He also approved that IER would develop a model interpreter based on the windrose approach of HTM and give this interpreter to the public. Dr. David Lee, AEA Technology, provided help on details of the chemical mechanism, and approved that IER employs a HTM-like windrose trajectory model in the *EcoSense* software for application in the ExternE project.

Dr. Erik Berge from EMEP MSC-W, Norwegian Meteorological Institute Oslo, Norway, provided emission data (SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub>) and meteorological data (wind speed, wind directions, precipitation) on the EMEP grid.

The Industrial Source Complex (ISC2) dispersion model linked to the *EcoSense* package has been developed by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Technical Support Division, Research Triangle Park, North Carolina 27711.



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## 1 INTRODUCTION/GENERAL REMARKS

*EcoSense* is an integrated computer system developed for the assessment of environmental impacts and resulting external costs from electricity generation systems. Based on the impact pathway approach established in the EC ExternE-Project, *EcoSense* provides relevant data and models required for an integrated impact assessment related to airborne pollutants.

One of the major objectives of the *EcoSense* development was to produce a user friendly system that is capable of performing a highly standardized impact assessment procedure with a minimum of data required as input from the user. Besides of the technical data of the facility to be analyzed, only a set of site specific meteorological data required for local air transport modeling has to be added by the user. All other data are provided by the system, so the user does not lose time by the tedious compilation of data. However, it is obvious that this approach limits the flexibility of the system. Although the various modules of the system have a potential for high flexibility, the current *EcoSense* version is limited to a set of standard applications that are very easy to carry out. A basic decision during the design phase of the system with respect to an easy handling of the system was the selection of a single coordinate system, the European wide EUROGRID. The *EcoSense* system provides an interface supporting the transfer of geographical data according to the EUROSTAT NUTS classification to the EUROGRID system, so that the user is able to modify data characterizing the reference environment.

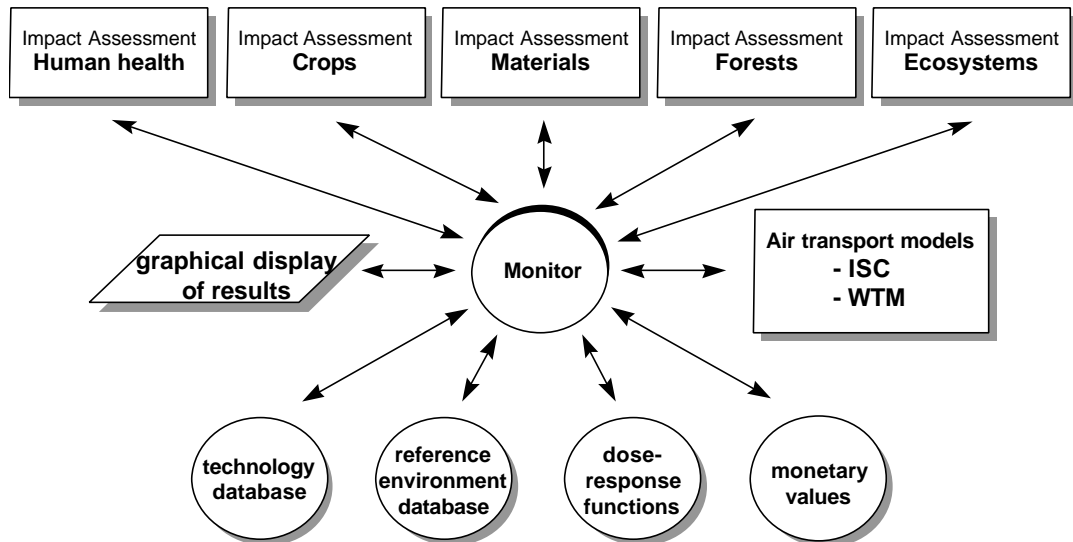
### 1.1 Structure of the *EcoSense* system

Figure 1 shows the general structure of the *EcoSense* System. The main modules are

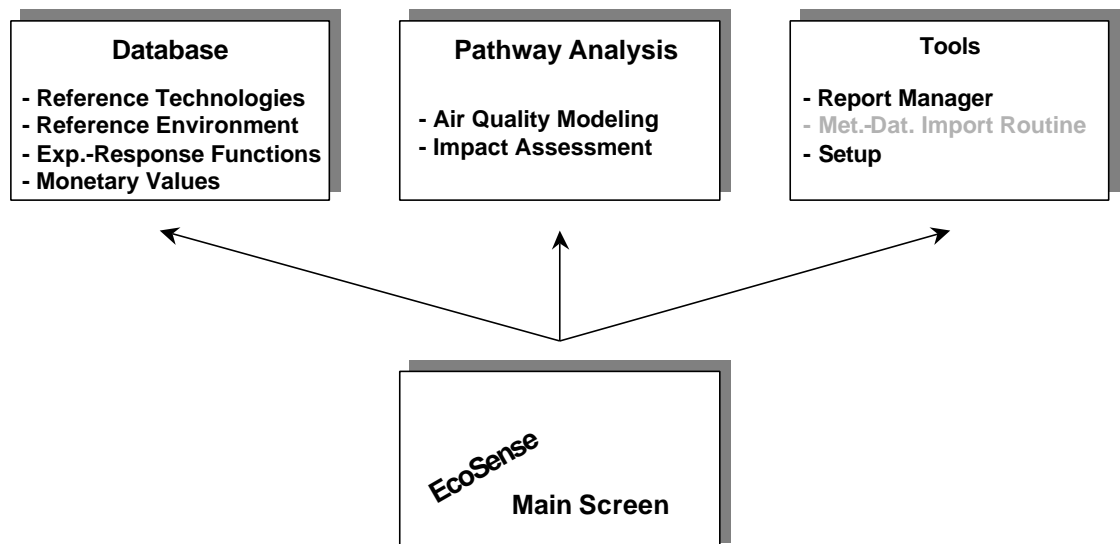
- a database system comprising several sub-modules,
- air transport models completely integrated into the system,
- impact assessment modules, and
- tools for the evaluation and presentation of results.

From a user's perspective, the structure of the system appears to be quite different from the technical structure (see Figure 2). An important feature of the system design was the strict separation between the database module and the air transport modeling/impact assessment modules in order to guarantee consistency among the various levels of data (input data, intermediate results, final results). If for instance the user modifies the SO<sub>2</sub>-emission factor of a facility specified in the reference technology database, the system

automatically deletes all related intermediate (e.g. results from air transport modeling) and final results (e.g. physical impacts) from the database.



**Figure 1** Modular structure of the *EcoSense* model



**Figure 2** The *EcoSense* modules from a user's perspective

## 1.2 Software used

The following software has been used for the implementation of the *EcoSense* system:

- Microsoft C for Windows
- Borland Paradox
- Borland Paradox Engine

The use of a high level programming language in combination with a relational database system seems to be an appropriate technical solution for processing and managing large amounts of data required for impact assessment. The Paradox Engine organizes the transfer of data between the database tables and the C-Program.

## 1.3 Air quality models used

*EcoSense* 2.0 provides two air transport models completely integrated into the system:

- The *Industrial Source Complex Model* (ISC) is a Gaussian plume model developed by the US-EPA. The ISC is used for transport modelling of primary air pollutants (SO<sub>2</sub>, NO<sub>x</sub>, particulates) on a *local* scale (100 km x 100 km around the power plant site).
- The *Windrose Trajectory Model* (WTM) is a user-configurable trajectory model based on the windrose approach of the Harwell Trajectory Model developed at Harwell Laboratory, UK. For current applications, the WTM is configured to resemble the atmospheric chemistry of the Harwell Trajectory Model, other mechanisms can be adopted as well. The WTM is used to estimate the concentration and deposition of acid species on a European wide scale.

## 1.4 Reference Environment Database

The reference environment database provides receptor specific data and meteorological data based on the EUROGRID-coordinate system. The area covered in the database ranges from EUROGRID grid element (-7/-20) to (20/23). Receptor data are available on both the large EUROGRID-cells (10 000 km<sup>2</sup>) and the small EUROGRID-cells (100 km<sup>2</sup>). Data on the fine grid are used for the *local* scale impact assessment close to the power plant site, while data on the large grid are used for the *regional* (i.e. European wide) impact assessment.

Receptor data are available for population, production of various crop types, total agricultural area, building material, forests and natural ecosystems. The database provides meteorological data (wind speed, wind direction, precipitation) on the large EUROGRID grid, these data are used for regional range air transport modelling. To use the Industrial Source Complex Model for local scale air transport modelling, the user has to add a set of hourly site specific meteorological data (see section 6.3). *EcoSense* provides a routine to import the required data from a text-file into the database.

‘Reference Environment’ data included in the *EcoSense* database

	Resolution	Source
<b>Receptor distribution</b>		
Population	EUROGRID 100 x 100 km and 10 x 10 km	EUROSTAT REGIO
Production of wheat, barley, sugar beat, potato, oats, rye	EUROGRID 100 x 100 km and 10 x 10 km	EUROSTAT REGIO
Inventory of natural stone, zinc, galvanized steel, mortar, rendering, paint	EUROGRID 100 x 100 km	Extrapolation based on inventories of some European cities
Forest areas in 4 sensitivity classes	EUROGRID 100 x 100 km	Stockholm Environment Institute (SEI), York, UK
Areas of 9 natural ecosystems	EUROGRID 100 x 100 km	Stockholm Environment Institute (SEI), York, UK, Institute of Terrestrial Ecology (ITE), Grange- over-Sands, UK
<b>Meteorological data</b>		
Wind speed	EUROGRID 100 x 100 km	EMEP
Wind direction	EUROGRID 100 x 100 km	EMEP
Precipitation	EUROGRID 100 x 100 km	EMEP
<b>Emissions</b>		
SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub>	EUROGRID 100 x 100 km	EMEP

## 1.5 The concept of local and regional range analysis

Various modules of the *EcoSense* system refer to a so called "local" and "regional" range analysis. The concept of local and regional range analysis

results from the need of performing a European-wide (regional) analysis based on an operational amount of data, but to take into account at the same time the spatial distribution of concentration and receptors at a high resolution within the highly affected area close to the power plant site. Models and data are provided in a way, that the standard impact assessment includes a local range analysis based on a 10 x 10 km grid (small EUROGRID-gridcells), covering an area of 10 x 10 gridcells, with the power plant located in the center of the local region. The regional range analysis is based on the large EUROGRID-gridcells (10 000 km<sup>2</sup>) and covers the whole of Europe.

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**Note** The regional range area overlaps the local range area, so that local and regional impacts should not be added up to calculate the total impact. A routine has been implemented to calculate the total impacts, avoiding a double counting and taking into account the more detailed results derived on the local range.

Impacts related to secondary pollutants (e.g. sulfate or nitrate aerosols, acid deposition) are only analysed on the regional scale, as the local scale Gaussian plume model covers primary pollutants only.

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## 1.6 Structure of the Manual

The *EcoSense* User's Manual does not provide any information on methodological aspects. For a full discussion of the methodological framework the reader should refer to e.g.

*European Commission, DG XII, Science, Research and Development, JOULE. ExternE - Externalities of Energy. Volume 2 Methodology, EUR 16521, 1995.,*

*European Commission, DG XII, Science, Research and Development, JOULE. ExternE - Externalities of Energy. Volume 7 Methodology 1998 Update, EUR 19083, ISBN 92-828-7782-5, 1999.,*

or to

*'Entwicklung eines rechnergestützten Instrumentariums zur Ermittlung und vergleichenden Bewertung der Gesundheits- und Umweltauswirkungen und der daraus resultierenden externen Kosten der Stromerzeugung', Endbericht an die Vereinigung Deutscher Elektrizitätswerke -VDEW- e.V., IER, Universität Stuttgart, 1997.*

The following sections give a description of how to use the *EcoSense* system, following the logical way of doing a complete impact assessment procedure, i. e.

- installation,
- defining the reference facility,
- defining exposure response functions,
- assigning monetary values to physical impact categories,
- air transport modelling,
- impact assessment, and
- evaluation of results.

## 2 INSTALLATION

### 2.1 Hardware requirement

*EcoSense* runs on an IBM-compatible PC with a 486 processor (or higher). 8 MB RAM are required, and to install and run the system you should have >30 MB free on your hard disk.

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<b>Note</b>	Ensure that the maximum size of an executable program under DOS is at least 490 kB (after starting your Windows) in order to run the ISC model properly (which is a DOS program).
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### 2.2 Installation

To install *EcoSense* 2.0, insert the *EcoSense* CD into your CD-ROM drive, and start `ECO2INST.EXE` from Windows. The installation program asks for a directory on your hard disk where *EcoSense* will be installed. Enter a directory path and click the "Unzip" button. The installation program copies all files and tables necessary to run *EcoSense* except `CTL3DV2.DLL`. If `CTL3DV2.DLL` is not yet installed on your system, copy the file `CTL3DV2.DLL` to your Windows System directory where several other `.DLL` files may be located.





### 3 THE *ECOSENSE* MAIN SCREEN

After starting the *EcoSense* system, the *EcoSense* main screen (further referred to as the main screen) appears. You start any activity from the main screen's menu. The menu structure is as follows:

- 
- *System*
    - *Pathway Analysis* Start your impact pathway analysis (including air transport modeling and impact assessment). Note that you should have specified your reference facility before in the database module.
    - *Database*
      - *Reference Technology Database*
        - *New data:* Define a new reference facility.
        - *Edit data:* Edit data of a previously defined facility.
      - *Reference Environment Database:*
        - *Edit data:* Edit receptor data in NUTS administrative units.
      - *Exposure Response Functions*
        - *Crops* Define/edit an exposure response function
        - *Forest* Define/edit an exposure response function
        - *Human Health* Define/edit an exposure response function
        - *Material* Define/edit an exposure response function
        - *Monetary Values:* Assign monetary values to impact categories
    - *Exit:* Close the *EcoSense* System
  - *Tools*
    - *Generate Report:* Generate a report of the results
    - *Print Report:* Print report
    - *Import ISC\_Met. Data:* Import meteorological data required by the ISC-air transport model from an ASCII file to the database.
  - *Setup*
    - *Reference Technology Database*
      - *Tech. Data Min/Max:* Define minimum and maximum values for the input controller
    - *Industrial Source Complex Model*
      - *ISC Min/Max:* Define minimum and maximum values for the input controller
    - *Reference Environment Database*
      - *Risk Group Fractions:* Specify the fraction of specific risk groups within the total population
-



## 4 THE DATABASE INTERFACE

### 4.1 The Reference Technology Database

Open the Reference Technology database to define a new reference facility. Select the items <System> <Database> <Reference Technology Database> <New data> from the main screen's menu.

The purpose of the first dialogue (Figure 3) is to specify some general characteristics of the reference facility. Use the mouse or the tab/shift-tab key to move around in the window.

EcoSense - Reference Technology Database

Facility Characteristics

Technical Characterization

Energy Group: Fossil

Energy Source: Coal

Process Step: Generation

Operational Phase: Operation

Localization

Region: Europe

Country: Germany

Site: Lauffen

Facility Identification

Facility Id: LACOAL

Facility Shortname: Lauffen coal fired power plant

Facility Description: 600 MW coal fired power plant, DENOX, 7000 hours per year, located at Lauffen, ...

Regional Range Analysis only

OK... Reset Cancel

Figure 3 Specification of a facility's general characteristics

### *Technical Characterization*

Specify the energy group, energy source, process step, operational phase and mode of the facility by selecting one of the options offered in the list boxes.

### *Localization*

Select the specific country from the Country List-Box, and write the facility's site into the *Site*-Edit-field.

### *Facility Identification*

Enter an alpha-numeric facility-identification flag (maximum 8 character) into the *Facility Id* edit-field. Although the program needs the facility-id for internal use only, some of the temporary files use the facility-id as filename, so that a descriptive filename is helpful. The program ensures that the Id is unique.

Write an alpha-numeric short-name of the facility (maximum 32 characters) into the *Facility Shortname* edit-field. The short name should be descriptive, it is used in several other screens, mainly for the identification and selection of the facility. The program ensures that the facility shortname is unique.

For the purpose of documentation, you might add (optional) a brief description of the facility's main characteristics (maximum 255 characters).

The WTM model for regional range air transport modeling requires less data than the ISC model. So, in the case you intend to perform a regional range analysis only, click the *Regional Range Assessment only* button, and in the following window you are asked only for those data required by the WTM-model.

Clicking on the *OK* button, a new window appears depending on the fuel source and the process step of the fuel chain.

#### 4.1.1 Fossil fired power plants

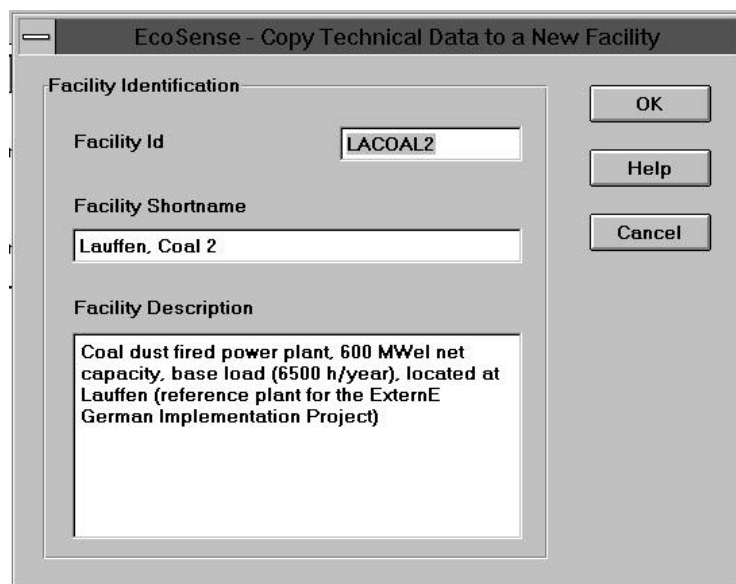
Figure 5 shows the datasheet relevant for fossil fired power plants. Please fill in all the technical data you are asked for. Use the mouse or the tab/shift-tab key to move around. The range of values that is accepted by the system is defined in the *EcoSense-Setup* (see section 7.1). Clicking the *OK* button, the current data are stored in the Reference Technology Database.

To edit data of a previously specified facility select the items <System> <Database> <Reference Technology Database> <Edit Data> from the main screen's menu. Select the facility that you want to modify from the *Facility* list-box. After the selection of a facility, all edit-fields are filled with the current values. Use the mouse or the tab key to select the value you want to modify. After editing this value, use the mouse or the tab key to go to the next field, thus confirming the modification. After clicking the *OK* button, the new data will be stored in the database, and all intermediate and final results that are dependent on the previously modified value are deleted (after confirmation from the user) in the database system to ensure consistency between the technical data and the results. Click the *Delete* button to remove all data (technical data as well as all results) related to the selected facility from the database.

Facility: Coal fired reference plant		
Gross Electricity Production	652.2	MW
Electricity Sent Out	600	MW
Full Load Hours per Year	6500	h
SO <sub>2</sub> Emissions	100	mg/Nm <sup>3</sup>
NO <sub>x</sub> Emissions	180	mg/Nm <sup>3</sup>
TSP Emissions	20	mg/Nm <sup>3</sup>
Micropollutants	As	microgram/Nm <sup>3</sup>
Flue Gas Volume	1.72074e+006	Nm <sup>3</sup> /h
Flue Gas Temperature	403.1	K
Stack Height	240	m
Stack Diameter	10	m
Anemometer Height	240	m
Geographical Latitude (decimal)	49.08	degree
Geographical Longitude (decimal)	9.18	degree
Elevation at Site	165	m

**Figure 5** Reference Technology Database interface for fossil power plants

In the case you want to perform a sensitivity analysis and change specific parameters without losing all the related results, you can copy the technical data of the selected facility to a new facility and then modify the technical characteristics of the new facility. After clicking the *Copy* button, the screen shown in Figure 6 comes up. The user is asked for Facility Id, Facility Shortname and Facility Description of the new facility. After clicking the *OK* button, the previous screen for editing technical data appears again, showing the same set of technical data now for the new facility, which can be modified without losing any results.



**Figure 6** Copy technical data to a new facility

#### 4.1.2 Nuclear fuel chain: power plant

The datasheet related to the normal operation of nuclear power plants is shown in Figure 7. To perform a simplified accident consequence assessment implemented in *EcoSense*, you have to specify the core inventory and the accident conditions. By clicking on the *Core Inventory Configuration* and *Accident Scenario Configuration* buttons you have access to the related dialogues shown in Figure 8 and Figure 9. Like in the case of fossil plants, data from a previously defined plant can be copied to a new plant.

Facility: Nuclear-Power Plant

Annual Electricity Generation: 10.725 TWh

Annual Emissions of:

Kr-85	0	TBq
Total noble gases	16.08	TBq
H-3	0.85	TBq
C-14	0.078	TBq
Iodines	1.01e-005	TBq
Particulates	3.7e-006	TBq

Type:  PWR  BWR

Buttons: Delete, Copy..., OK, Reset, Cancel, Core Inventory Configuration..., Accident Scenario Configuration...

Figure 7 Reference Technology Database interface for nuclear power plants

Core Inventory Configuration

Inventory (Bq):

Noble gases	1.5e+019
Iodines	3.18e+019
Alkali metals	7.84e+017
Tellurium group	8.88e+018
Alkaline earth metals	1.55e+019
Noble metals	2.68e+019
Metal oxides	1.26e+020

Buttons: Reset, OK, Cancel

Figure 8 Core inventory configuration

Accident Scenario Configuration

General accident description

Description: DRSB 2

Frequency of occurrence / year: 1e-007

Release fraction of core inventory:

Noble gases	1
Iodines	0.37
Alkali metals	0.37
Tellurium group	0.23
Alkaline earth metals	0.14
Noble metals	2.5e-006
Metal oxides	0.012

Release conditions:

Starting hour: 2

Release height: 10 m

Energy release: 55.5 MW

Buttons: Reset, Delete, Accept, Cancel

Figure 9 Accident scenario configuration

### 4.1.3 Nuclear fuel chain: mining and milling

The dialogue shown in Figure 10 asks for the technical data required to calculate impacts from uranium mining and milling.

**EcoSense - Nuclear - Mining/Milling**

Facility: Nuclear mining a. milling

Fuel cycle U3O8 requirement per TWh: 23.66 t

Mine

Annual production of U3O8: 2011 t

Annual emission of Rn-222: 1600 TBq

Mill

Annual production of U3O8: 1900 t

Annual Emissions of:

Pb-210	0	GBq
Po-210	0	GBq
Rn-222	9200	GBq
Ra-226	0	GBq
Th-230	0	GBq
U-238	0	GBq

Uranium mill tailings

Tailings generation: 1 ha/GWa

Operation

Emission rate: 6 Bq/m2/s

Release duration: 5 years

Abandoned tailing piles

Emission rate: 3 Bq/m2/s

Release duration: 10000 years

**Figure 10** Reference Technology Database interface for uranium mining and milling

### 4.1.4 Nuclear fuel chain: reprocessing

The dialogue shown in Figure 10 asks for the technical data required to calculate impacts from the reprocessing stage.

**EcoSense - Nuclear - Reprocessing**

Facility: Nuclear reprocessing

Annual Capacity of reprocessed fuel (energy equivalent): 17.5 GWa

Reprocessing: Annual Release of

H-3	3.73	TBq
C-14	5.8	TBq
Kr-85	58000	TBq
I-129	0.00416	TBq
I-131	5.76e-005	TBq
Cs-137	0	TBq

**Figure 11** Reference Technology Database interface for reprocessing



## 4.2 The Reference Environment Database

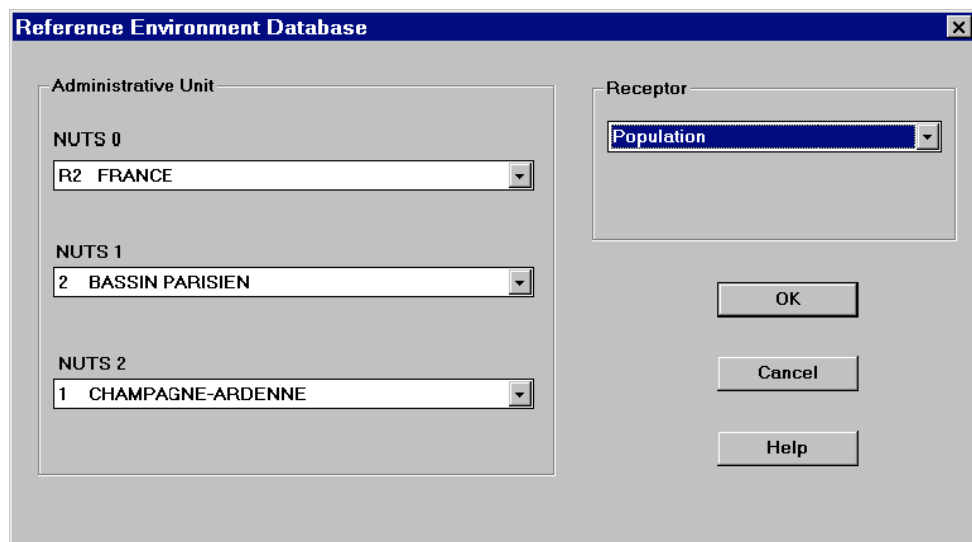
The Reference Environment Database interface supports the display and editing of receptor data according to administrative units (using the EUROSTAT NUTS categories). The module organises the transfer of data between administrative units and the EUROGRID coordinate system.

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**Note** The forest and natural ecosystem areas are not derived from administrative units, hence these receptor areas *cannot* be modified with this interface. They are taken from several land cover datasets with the help of a Geographic Information System (GIS).

---

Select the items <System> <Database> <Reference Environment Database> <Edit data> from the main screen's menu. In the dialog box shown in Figure 12 select the receptor you want to edit from the *Receptor*-list box. After selecting a receptor, a list of all 'NUTS 0' administrative units (countries) appears in the *NUTS 0*-list box. Select the administrative unit you want to edit by stepwise clicking through the *NUTS 0*, *NUTS 1*, and *NUTS 2* - list boxes. After confirming your selection by clicking the *OK*-button, the dialogue shown in Figure 13 appears, which contains a list of subregions of the region selected in the previous dialog box. In this dialog you can edit the numerical value for each subregion.



**Figure 12** Reference Environment Database Dialog box 1.

**Figure 13** Reference Environment Database Dialog box 2 (Edit dialog).

The lists box shows the NUTS code, the name of the administrative unit (if found) and the current value for the selected receptor. In the column „Current value“ one of the following entries may be displayed:

Current value	Meaning
<i>(a number)</i>	A value exists already in the database for exactly this administrative unit
..	A value exists in the region covering all administrative units in the list. In this case changes are accepted only if you edit <b>all</b> entries in order to keep the coverage of the region complete. The value of the covering region will be deleted then.
-->	Values exist in smaller subregions of the administrative unit. If you enter a new value for this line and push OK, all entries in the subregions subdividing this administrative unit will be deleted.
<i>(empty)</i>	No value was found, the current value is assumed to be zero.

Select the administrative unit you wish to edit and enter a new value and a new reference string into the edit boxes below. After clicking the *OK*- button, all changes are stored in the database and the input is transformed to the EUROGRID. The calculation of the grid transformation may take some time.

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**Note** You can edit values on any NUTS level you want. But the way down to smaller regions must be taken step by step. For example, if the current database has one entry on NUTS level 0 (i.e. one value for the whole of the country) you cannot enter new values for NUTS level 3 (the finest resolution). Instead, first you have to give values for NUTS level 1, then NUTS level 2, then NUTS level 3. This is because the program always expects a unique coverage for the countries.

Be careful when editing a field with the sign „- - >“. This sign indicates that values for the region exist already in subregions. If you enter a new value for this line, all entries in the subregions will be deleted.

The transformation of the NUTS data of a large region to the grids is a time-consuming task. The transformation of a complete data set for Europe for one receptor to the 100 km<sup>2</sup> EUROGRID takes about 1 day on a Pentium 133 MHz. So, please be patient!

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## 4.3 Exposure Response Functions

### 4.3.1 Add a new exposure response function

To define a new exposure response function, select the items <System> <Database> <Exposure Response Function> <Human Health> (or other receptors), and <New Data> from the main menu, leading to the screen shown in Figure 14. Use the *Receptor sub-group* list-box, *Impact* list-box and *Pollutant* list-box to specify the receptor sub-group (e.g. children, asthmatics), the impact and the pollutant the new exposure response function refers to by clicking on one of the items in each list-box.

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**Note** For forests exposure-response functions depending on *two* pollutants can be added; for materials and natural ecosystems functions depending on *three* pollutants. Accordingly in these interfaces two respective three pollutant list boxes are displayed. If only one or two pollutants are relevant the remaining pollutant list boxes should be left empty.

---

Use the big edit-field to enter the exposure response function as a mathematical expression. The *Constant/Variables* list-box provides a list of constants and variables for which numerical values are available in the system and thus can be used to build up the exposure response function. To get some information on units etc. of the constants and variables offered in the list-box, click on the *Explain*-button after selecting one of the items in the *Constants/Variables* list-box. Items from the list-box are copied into the edit-field by clicking on the *Select*-button.

Besides of the basic mathematical operations (+,-,\*,/), a set of mathematical functions listed in the *Math. Functions* list-box is supported. Click on a function in the list-box to copy it into the edit-field, and insert text between the brackets. Click the *Accept*-button to confirm the exposure response function after writing it into the edit field. The syntax of the function is checked, and in the case of syntax errors an error message appears.

#### *Low, mid and high estimate*

To take into account information on confidence intervals for calculating a possible range of results, the user can define three different functions representing a low, mid and high estimate. Click the *low*, *mid* or *high* radio-button before writing the respective function into the edit-field.

*Define a threshold*

To define an exposure response function with threshold (i.e. no effects at concentrations below the threshold), click the *Threshold* check-box at the bottom of the screen and enter the numerical value into the related edit-field. Note that you can define a single threshold value only for a set of related low/mid/high functions.

**Figure 14** Add a new exposure response function

---

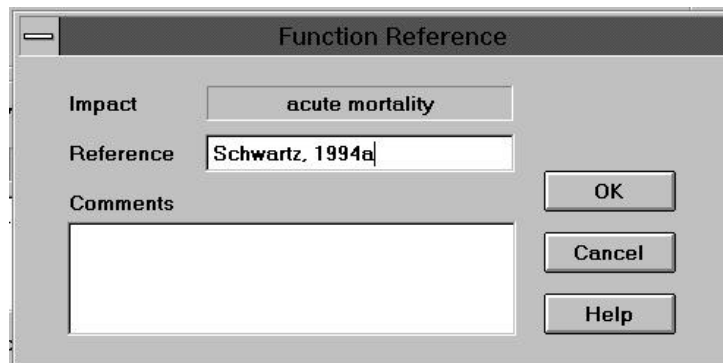
**Note** Clicking one of the low/mid/high radio buttons before you terminate the editing of a function by clicking the *Accept*-button leads to a loss of the current content of the edit-field.

The current version requires the definition of a function for the low, mid and high case. If you want to work with a single function only, save the same function as a low, mid and high function. (Use the Windows clipboard functions to copy a function: mark the expression you want to copy with the mouse (left button down), press the <Ctrl> and <Ins> keys to copy the expression into the clipboard, click the low, mid or high radio-button, click the edit field to make it active and then press the <Shft> and <Ins> keys to copy the expression from the clipboard into the edit-field.)

---

### *Reference*

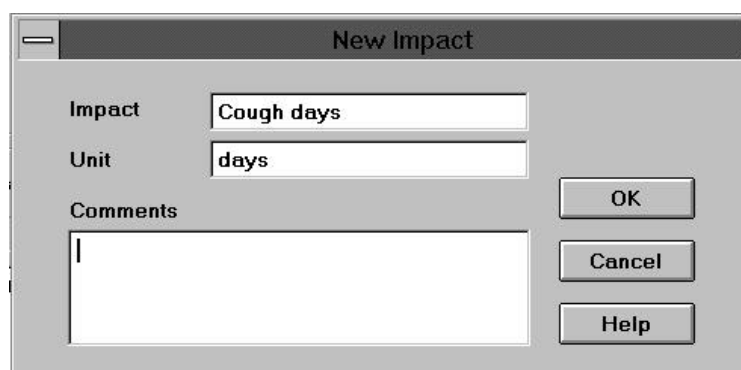
Click on the *Reference*-button to open the *Function Reference* dialogue (Figure 15). Enter the reference and comments into the respective edit-fields. Click the *OK*-button to confirm and to go back to the previous screen. Note that the reference entry is used for the identification of the exposure response function in various list-boxes in other modules of the system.



**Figure 15** Specification of a reference related to an exposure-response function

### *Define a new impact*

In the case the exposure response function to add is related to a physical impact that is not yet included in the *Impact* list-box, click the *New Impact* button to define a new impact in the *New Impact* dialogue (Figure 16). Enter the type of impact, the unit to measure the impact and comments into the respective edit-fields. Click the *OK*-button to confirm and to go back to the previous screen.



**Figure 16** Define a new impact

### 4.3.2 Edit existing exposure response functions

Select the items <System> <Database> <Exposure Response Functions> <Human Health> (or other receptors) and <Edit Data> from the main menu to modify previously defined exposure response functions (Figure 17). After selecting one of the items in the *Function* list-box by clicking on it, the corresponding receptor sub-group, impact, and pollutant is displayed in the respective text-fields, and the mathematical function is shown in the edit-field. Delete the function by clicking on the *Delete*-button, or edit the mathematical expression in the edit field. Editing a function is similar to the procedure of defining a new exposure response function described above. After confirming the modifications by clicking the *OK*-button, all intermediate and final results related to the modified or deleted function are deleted from the database system.

Human Health - Exposure-Response Relationships

Function: **Abbey - chronic bronchitis - adults - Nitrate**

Receptor sub-group: **adults**

Impact: **chronic bronchitis**

Pollutant: **Nitrate**

Variables: **[Empty]** **Explain** **Math. Functions** **[Empty]**

**Select**

Impact in [ **cases** ] =  low  mid  high

**4.9 \* DeltaConcentration \* Population \* adults /100000**

Threshold for **Nitrate** **0**  $\mu\text{g}/\text{m}^3$

**Reference**

**Accept**

**Delete**

**OK**

**Cancel**

**Figure 17** Edit a previously defined exposure-response function

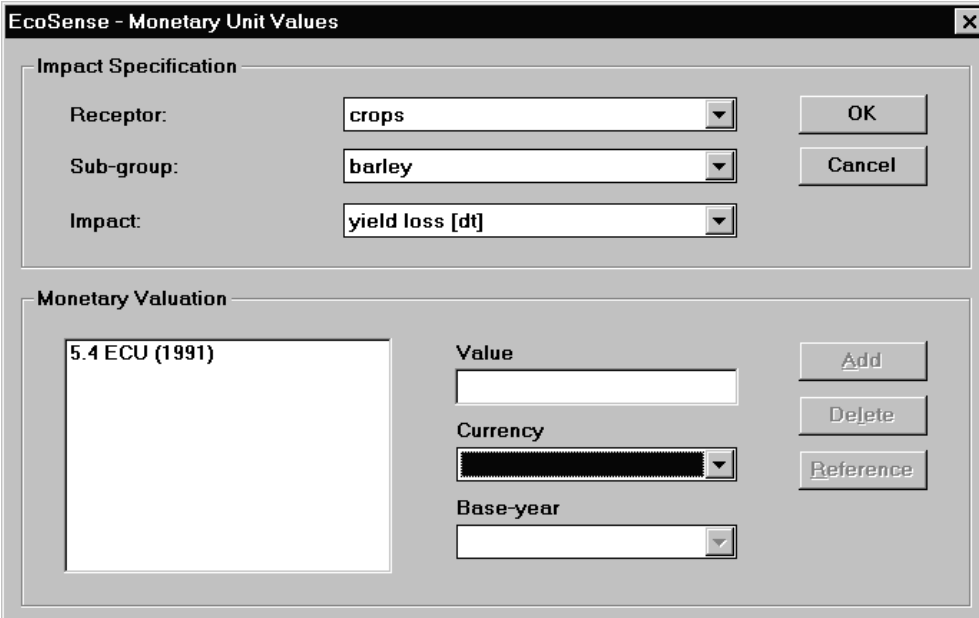
## 4.4 Monetary Values

To add or modify monetary values select the items <System> <Database> and <Monetary Values> from the main menu. Use the *Receptor* list-box, *Sub-group* list-box and *Impact* list-box in the *Impact Specification* panel to select the physical impact related to the monetary value you want to add or edit (Figure 18). After selection, the left-hand edit-field in the *Monetary Valuation* panel shows a list of the monetary values related to the selected impact that are currently available in the database.

---

**Note** Monetary values can be defined only for impacts for which an exposure response function has been defined before.

---



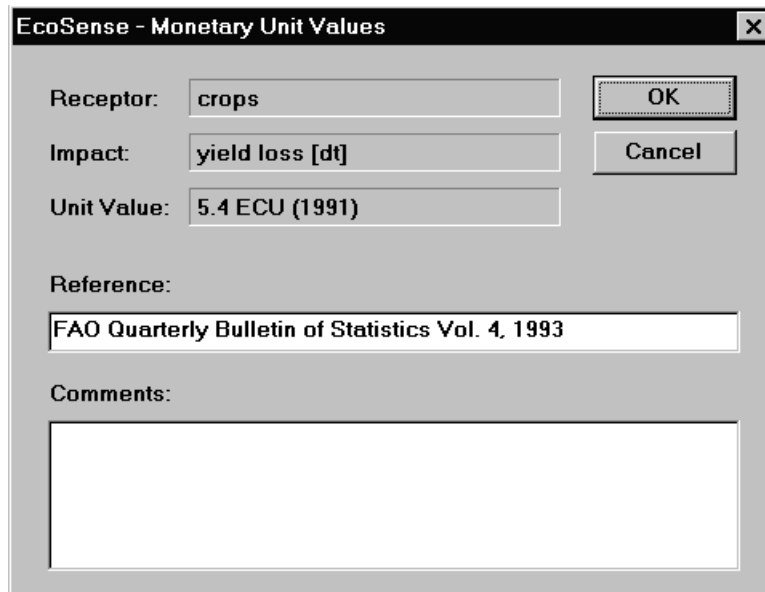
**Figure 18** Add/edit monetary values

### *Add a new monetary value*

To add a new monetary value, enter the numerical value into the *Value* edit-field and select the related currency and base year in the *Currency* and *Base-year* list box. After clicking the *Add*-button, the new value is added to the list of monetary values shown in the edit-field.

Click on the *Reference*- button to open the dialogue shown in Figure 19. Enter reference and comments into the respective edit-fields. Click the *OK*-button to confirm and to go back to the previous screen.





**EcoSense - Monetary Unit Values**

Receptor: crops

Impact: yield loss [dt]

Unit Value: 5.4 ECU (1991)

Reference:  
FAO Quarterly Bulletin of Statistics Vol. 4, 1993

Comments:

**Figure 19** Specification of a reference related to a monetary value

*Delete a monetary value*

Mark the monetary value that you want to delete by clicking on it in the left-hand edit-field of the *Monetary Valuation* panel and then click on the *Delete*-button. Note that all intermediate and final results related to the deleted monetary value are deleted from the database system.

Click on the *OK* or *Cancel* button to confirm/cancel the modifications and to go back to the main menu.



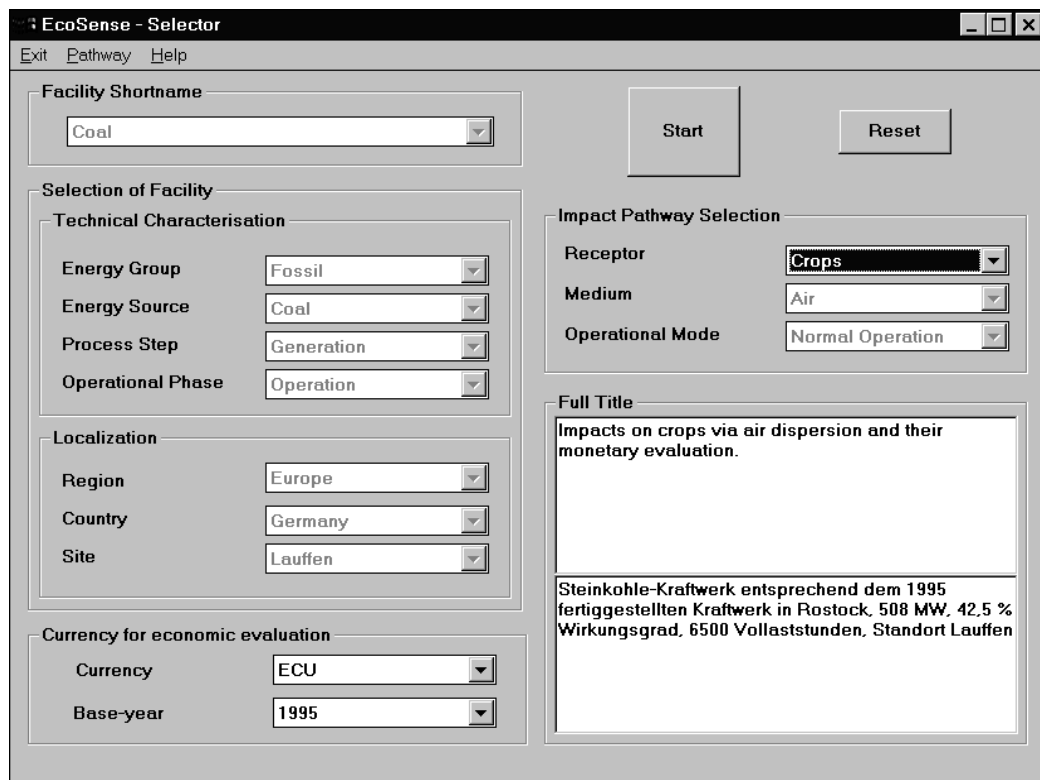
## 5 PATHWAY ANALYSIS

After defining your reference facility, you can now start the impact assessment procedure by selecting the items <System> <Pathway Analysis> from the main screen. Note that once you have started the impact pathway module, for the purpose of consistency, you cannot edit any of the data previously specified in the database module.

### 5.1 Selector

After selecting <Pathway Analysis> from the main screen, the *Selector* dialogue appears (Figure 20). In the Selector you specify the facility to be analyzed (either by selection from the *Facility-Shortname* list-box or by going step by step through the *Technical Characterization/Localization* List-boxes) as well as the specific pathway (by selecting the receptor from the *Receptor* list box). After having specified both facility and impact pathway, click the *Start* button to call the Atmospheric Modeling screen that organizes communication with the air quality models. Note that once you have done all your air transport modeling, you can call the impact assessment module directly from the Selector by selecting the <Pathway> <Impact Assessment> items from the Selector's menu, so that you can avoid to call the Atmospheric module every time you want to perform an impact assessment.

Specify the currency and the base-year for which results should be calculated in the *Currency for economic evaluation* panel.



**Figure 20** The Selector dialogue

## 5.2 Atmospheric Modeling

The left hand side of the Atmospheric Modeling dialogue (Figure 21) indicates for which pollutant/range combinations results from previous air transport module runs are available. If the available data are sufficient for your impact assessment purposes, start the impact assessment module by clicking the *Pathway Analysis* button. If you want to start an air transport model run, specify the model and - in the case of the ISC Model - the pollutant and click the *Transport Modeling* button.

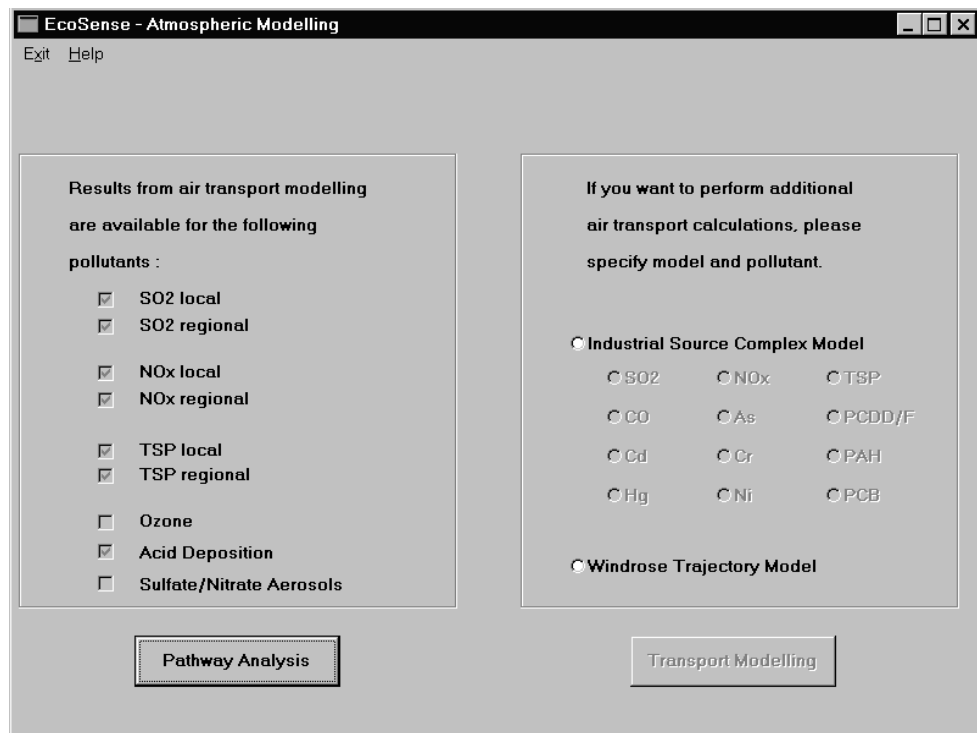
---

**Note** The ISC model needs a set of site specific meteorological data not included in the *EcoSense* package. *EcoSense* provides a routine to import the data from a formatted text-file into the database. See section 6.3 for further information.

---

By running either the ISC or the WTM model, *EcoSense* creates several temporary files which are located in the `.\ecosense\tmp` directory. As an informed user might use these files for documentation, they are not automatically deleted after the termination of an air transport model run. A new model run overwrites the temporary files.

---



**Figure 21** The *Atmospheric Modeling* dialogue

The set of diffusion coefficients used by the ISC depends on the facilities stack height. The coefficients are derived from experiments in Germany, with

$$\sigma_y = p_y \cdot x^{q_y}$$

$$\sigma_z = p_z \cdot x^{q_z}$$

with  $x$  distance from source in [m]

$p_y, p_z$  as shown in Table 1 below.

**Table 1** Diffusion coefficients  $p_y$  and  $p_z$ 

Height (m)	Stability Category				
		$p_y$	$q_y$	$p_z$	$q_z$
< 60	A	1.503	0.833	0.151	1.219
	B	0.876	0.823	0.127	1.108
	C	0.659	0.807	0.165	0.996
	D	0.640	0.784	0.215	0.885
	E	0.801	0.754	0.264	0.774
	F	1.294	0.718	0.241	0.662
60 - 120	A	0.170	1.296	0.051	1.317
	B	0.324	1.025	0.070	1.151
	C	0.466	0.866	0.137	0.985
	D	0.504	0.818	0.265	0.818
	E	0.411	0.882	0.487	0.652
	F	0.253	1.057	0.717	0.486
> 120	A	0.671	0.903	0.0245	1.500
	B	0.415	0.903	0.033	1.320
	C	0.232	0.903	0.104	0.997
	D	0.208	0.903	0.307	0.734
	E	0.345	0.903	0.546	0.557
	F	0.671	0.903	0.484	0.500

### 5.3 Impact Assessment Modules

In the following, only the human health impact pathway is described in detail. Other impact pathways have a similar structure.

The impact assessment module offers two different approaches:

- A step-by-step analysis for each single combination of pollutant and exposure-response relationship, with the possibility of presenting detailed intermediate results (e.g. maps showing incremental air pollution concentrations).
- A *Full Assessment Procedure* performing an automatised impact assessment of all combinations of pollutant/exposure-effect relationships.

#### 5.3.1 Step-by-step analysis

The dialogue (Figure 22) is organized according to the logical structure of the impact pathway (environmental burden, air quality modeling, impact assessment, valuation).

Activity			
Facility	Coal		
Pollutant	SO2	Emissions	209.1 g/MWh
Ambient Air Concentration			
Range of Analysis		Background	Map
<input checked="" type="checkbox"/> Local		Increment	Map
<input checked="" type="checkbox"/> Regional			
Impact Assessment			
Exp.-response function	total resp. hosp. admission de Leon		
Calc Additional health events per TWh	Low	0.022	Population Distribution Map
	Mid	0.24	
	High	0.45	Impact distribution Map
Valuation			
Value of impact	7870 ECU ExternE		
Calc Damage per kWh	Low	0.0002 mECU	
	Mid	0.0019 mECU	
	High	0.0035 mECU	

Figure 22 The Human Health Impact Pathway dialogue

*Activity panel*

Select the pollutant to be analyzed in the *pollutant* list-box.

---

---

**Note** Only pollutants, for which both exposure-response functions and air transport modeling results are available in the database are included in the list.

In the impact pathway modules for forests, ecosystems and materials a pollutant mix, not a single pollutant, is selected. For forests the mix can consist of up to two pollutants, for ecosystems and materials of up to three pollutants.

---

---

*Ambient Air Concentration panel*

The *Range of Analysis* boxes indicate whether results from air transport modeling are available on the local or/and the regional range (box checked = data available). If both local and regional range data are available, and e.g. only a local range analysis is to be performed, the *regional range* box has to be unchecked by clicking on it.

By clicking on one of the *map* buttons, you can display the background concentration as well as the increment in concentration of the previously selected pollutant.

---

---

**Note** The map buttons are only active after performing at least one impact assessment calculation (the system loads the relevant data into memory for calculation only).

The local map is displayed when **only** the local range button is checked. In the case that both the local and the regional range boxes are checked, the regional range (i.e. European) map is displayed.

No data on background concentrations for particulates are currently available in the database.

In the impact pathway modules for forests, ecosystems and materials local analyses are not possible, so even if local results for relevant pollutants are available the local *Range of Analysis* box cannot be checked.

---

---

*Impact Assessment panel*

Select an exposure-response function from the *Exp.-response function* list box. Only functions related to the previously selected pollutant are included in the list. Click the *Calc* button to start the physical impact quantification.



**Note** In the impact assessment module for ecosystems there is an additional *Info* button, which becomes active, when a exp.-response function is selected. If clicked, a message window with additional information on the function is displayed.

*Valuation panel*

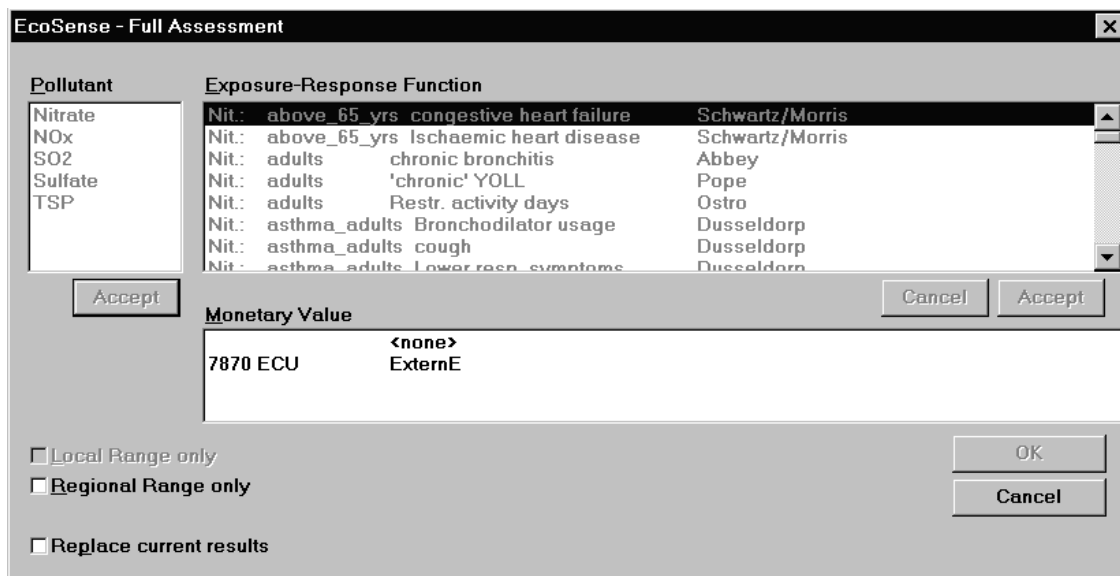
Select a monetary value from the list box. Only monetary values related to the impact specified by the previously selected exp.-response function are included in the list. Click the *Calc* button to start the calculation of costs.

**Note** After specifying the exp.-response function, you can immediately select a monetary value in the Valuation panel and then start the calculation of both physical impacts and economic damage at the same time by clicking the *Calc* button in the Valuation panel.

Use the <Save> item from the menu to save the current results to the database.

**5.3.2 Full Assessment procedure**

While the step-by-step analysis described above provides a high degree of transparency, it is not very comfortable to carry out a full fuel cycle evaluation. Thus, the Full Assessment procedure has been implemented, allowing a highly automatised analysis of impacts. Start the Full Assessment procedure by selecting the <Full Assessment> item from the menu (Figure 23).



**Figure 23** The *Full Assessment* dialogue

In the *pollutant* field a list of pollutants for which exp.-response functions and air transport modeling results are available is displayed. Select those pollutants that you wish to include in your full assessment by clicking on them with the mouse. Confirm the selection by clicking the *Accept* button.

---

**Note** In the impact pathway modules for forests, ecosystems and materials a pollutant mix, not a single pollutant, is selected. For forests the mix can consist of up to two pollutants, for ecosystems and materials of up to three pollutants.

---

After clicking the *Accept* button of the *pollutant* field, a list of exp.-response functions related to the selected pollutants is displayed in the *Exposure Response Function* field. Select those functions that you want to include in your full assessment by clicking on them with the mouse. Confirm the selection by clicking the *Accept* button. Note that the structure of the database system allows results to be stored only with **one** monetary value for each of the possible exposure-response functions. Thus, immediately after selecting one of the exposure-response functions, the *Monetary Value* field becomes active and you have to select one of the related monetary values.

The Full Assessment procedure automatically saves results to the database. In the case you have not checked the *Replace current results* box, you are asked for each single result before overwriting existing results from previous model runs. Click the *OK* button to start the calculation of physical impacts and economic damages.

## 6 THE *ECOSENSE* TOOLS

### 6.1 Report Manager

EcoSense supports the evaluation of results by generating two different types of reports:

- an ASCII text file in a 'readable' format with the extension *.rpt*, and
- an ASCII file pre-formatted for import into spreadsheet programs like Microsoft-Excel with the extension *.tab*.

Select the <Tools> <Generate Report> items from the main screen's menu to call the report manager (Figure 24).

---

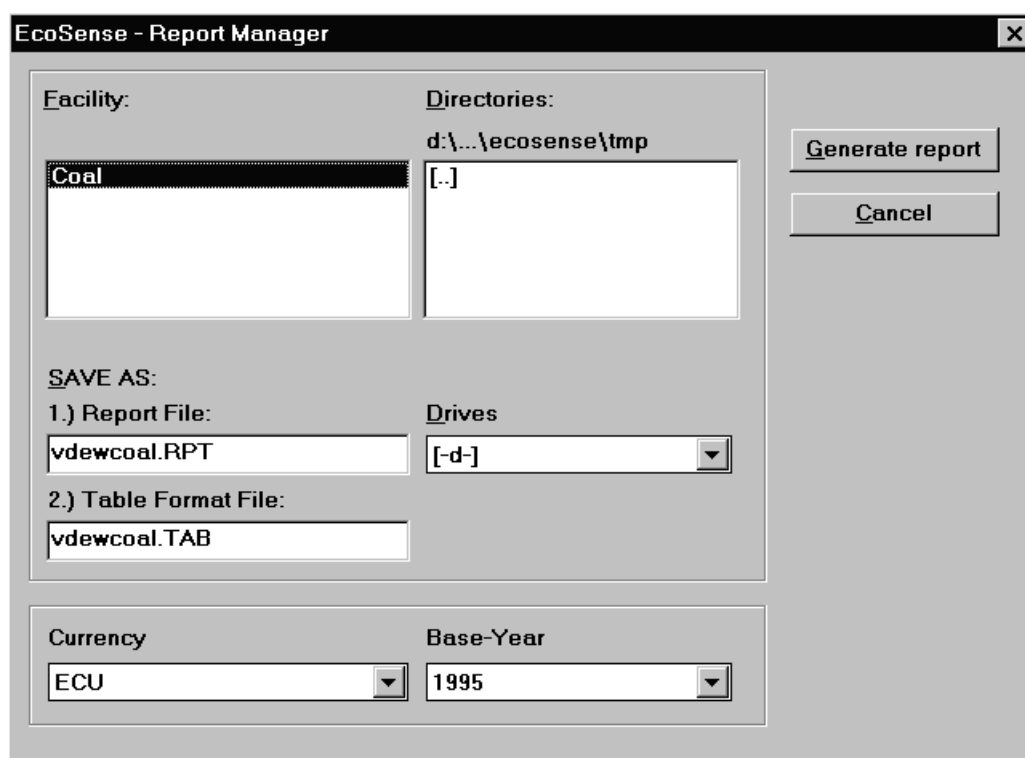
**Note** You can generate a report only if you have performed an impact pathway analysis and saved results to the database before.

---

Select the facility for which you want to create a report by double-clicking on one of the facility-shortnames listed in the *Facility* list-box. By clicking one of the shortnames, the default name of the report-file is shown in the *Save report as* edit-field, using the facility-id (previously specified in the reference technology database interface) and the *.rpt* and *.tab* extension. You might edit the filename, but ensure that you are using the *.rpt* extension for the text file, otherwise the print manager (see section 6.2) will not find the report-file.

Select the currency and base year to be used in the report for monetary values in the *User-defined currency* panel.

Use the *Directories* and *Drives* list-boxes to specify where the report will be stored. Click the *Generate report* button to start the generation of the report.



**Figure 24** *The Report Manager*

## 6.2 Print Manager

Select the <Tools> <Print Report> items from the main screen's menu. Like in standard Windows applications, select the report-file you want to print from the list and click the *Print* button.

---

---

**Note** Only files with the extension .rpt are included in the list-box.

---

---

## 6.3 Import ISC Meteorological Data

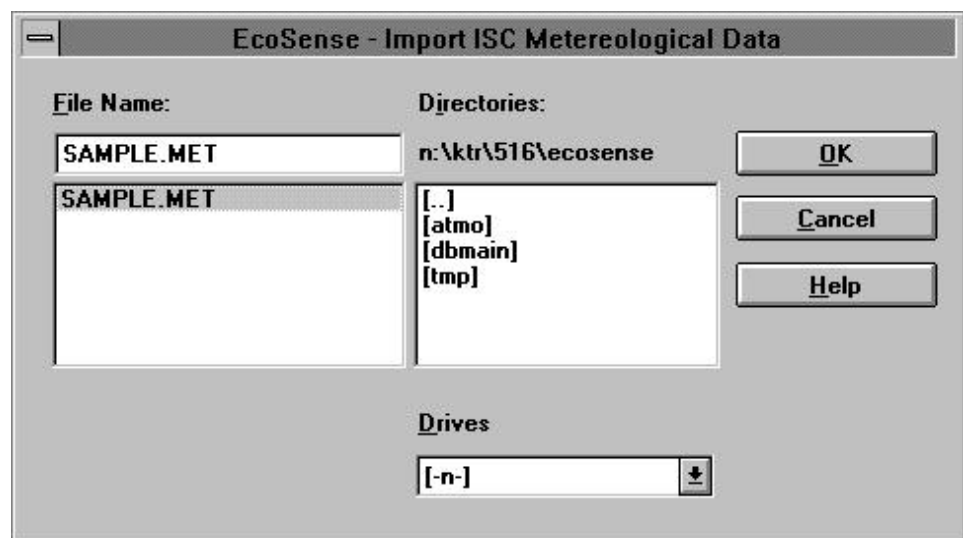
The ISC air transport model needs a set of site specific meteorological data that is not included in the *EcoSense* database. The user has to provide a formatted text-file (extension: .met) and use the import procedure to transfer data to the database. Select the items <Tools> and <Import ISC\_Met. Data> from the main screen's menu (Figure 25), select the relevant file and click the *OK*-button to start the import procedure. By reading the text-file, the system checks for consistency of the data, minimum and maximum values are specified in the *EcoSense* Setup (see section 7.2).

Use the *Directories* and *Drives* list-boxes and select the \*.met file by double clicking it in the *File Name* list-box. Click *OK* to start the data transfer.

---

**Note** The *EcoSense* package provides a test-file (test.met) located in the temporary directory (ecosense\tmp\test.met), containing meteorological data for a site in Germany. For the purpose of testing the *EcoSense* system, you might use this file. To do so, don't forget to change the longitude and latitude according to the geographic coordinates of your facility in the first record of the file.

---



**Figure 25** The *Import ISC Meteorological Data* dialogue

The \*.met text-file has the following format:

1. Record: Longitude of the reference facility  
Latitude of the reference facility

Then, one record for each hour of the year, each record containing the following data:

Year	(last two digits)
Month	
Day	
Hour	
Flow vector	in [degree] (0° = N)
Wind speed	in [m/s]
Ambient temperature	in [K]
Stability Class	(A=1, B=2, C=3, D=4, E=5, F=6)
Rural mixing layer height	in [m]
Urban mixing layer height	in [m]
Wind profile exponent	
Vertical potential temperature gradient	in [K/m]

Use a 'white space' (blank) as a separator.

A part of the test.met file is shown as an example in the following:

```
9.175 49.0816
90 1 1 1 85.4000 3.2000 272.6 5 339.8 339.8 0.1000 0.0170
90 1 1 2 95.0000 2.4000 272.2 6 283.7 283.7 0.2800 0.0240
90 1 1 3 108.1000 2.9000 272.1 6 284.3 284.3 0.3100 0.0240
90 1 1 4 125.0000 3.6000 272.1 6 333.7 333.7 0.2600 0.0240
90 1 1 5 129.7000 4.0000 272.1 6 381.0 381.0 0.2500 0.0230
90 1 1 6 135.5000 4.2000 271.9 6 442.4 442.4 0.3200 0.0200
90 1 1 7 138.2000 3.2000 271.6 6 447.8 447.8 0.4600 0.0170
90 1 1 8 138.5000 3.0000 271.3 5 422.0 422.0 0.4900 0.0140
90 1 1 9 142.0000 2.8000 271.3 5 411.6 411.6 0.5300 0.0100
90 1 1 10 161.8000 2.2000 271.2 3 378.4 378.4 0.5900 0.0000
90 1 1 11 168.5000 2.0000 271.2 2 342.6 342.6 0.4900 0.0000
90 1 1 12 175.2000 2.2000 271.3 2 319.2 319.2 0.2500 0.0000
90 1 1 13 178.0000 2.4000 271.3 2 312.6 312.6 0.0800 0.0000
90 1 1 14 34.5000 2.7000 271.3 5 299.9 299.9 0.0700 0.0090
.....
.....

90 12 31 20 88.4000 3.6000 280.7 5 356.2 356.2 0.6700 0.0090
90 12 31 21 92.9000 3.7000 280.6 5 372.4 372.4 0.6300 0.0100
90 12 31 22 95.0000 3.9000 280.6 5 394.1 394.1 0.5800 0.0100
90 12 31 23 95.1000 4.1000 280.5 5 420.2 420.2 0.5200 0.0090
90 12 31 24 94.1000 4.2000 280.4 5 451.5 451.5 0.4700 0.0090
```

## 7 SETUP

The Setup option in the main menu can be used to modify some of the default values used by the system.

### 7.1 Reference Technology Database input controller

Open a list of minimum and maximum values that are used by the input controller of the Reference Technology Database interface by selecting <Setup> <Reference Technology Database> <Tech. Data Min/Max> from the main menu. Use the mouse or the <Tab> key to move around in the screen. Click the *OK*-button to confirm modifications and to go back to the main screen.

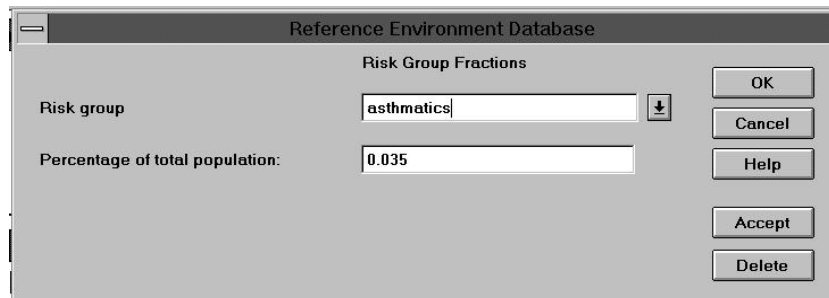
### 7.2 Import ISC meteorological data input controller

Open a list of minimum and maximum values that are used by the input controller of the ISC meteorological data import procedure by selecting <Setup> <Industrial Source Complex Model> <ISC Min/Max> from the main menu. Use the mouse or the <Tab> key to move around in the screen. Click the *OK*-button to confirm modifications and to go back to the main screen.

### 7.3 Human health risk groups

Some of the exposure response functions related to human health impacts refer to specific risk groups (e.g. children, asthmatics) within the total population. You can add risk groups or modify risk group fractions in the screen shown in Figure 26 after selecting <Setup> <Reference Environment Database> <Risk Group Fractions> from the main menu. To change a given risk group fraction, select the risk group in the *Risk group* list-box and edit the numerical value in the *Percentage of total population* edit-field. After confirming a modification by clicking the *Accept*-button, you can select a new item from the *Risk group* list-box. The set of new values is written to the database after clicking on the *OK*-button.

To add a new risk group, write the risk group's name into the *Risk group* list-box and specify the numerical value in the *Percentage of total population* edit field. Confirm by clicking the *Accept* and *OK*-button.



The screenshot shows a dialog box titled "Reference Environment Database". Inside, there is a section titled "Risk Group Fractions". It contains two input fields: "Risk group" with a dropdown menu showing "asthmatics" and a small downward arrow icon, and "Percentage of total population:" with a text input field containing "0.035". On the right side of the dialog, there are five buttons: "OK", "Cancel", "Help", "Accept", and "Delete".

**Figure 26** Add/edit risk group fractions within the total population



## 8 APPENDIX

### 8.1 *EcoSense* Data Requirement

The following list gives a summary of the data that are required to perform an evaluation of external costs using the *EcoSense* system.

#### *Fossil fired power plants*

##### **Technical Data:**

Gross electricity production	in [MW]
Electricity sent out	in [MW]
Full load hours	in [h]
SO <sub>2</sub> emissions	in [mg/Nm <sup>3</sup> ]
NO <sub>x</sub> emissions	in [mg/Nm <sup>3</sup> ]
Particulates emissions	in [mg/Nm <sup>3</sup> ]
Stack height	in [m]
Stack diameter	in [m] <sup>*)</sup>
Flue gas volume stream	in [Nm <sup>3</sup> /h]
Flue gas temperature	in [K] <sup>*)</sup>
Surface elevation at power plant site	in [m] <sup>*)</sup>
Anemometer height (at which wind speed data have been measured)	in (m) <sup>*)</sup>

<sup>\*)</sup> data required for local range analysis only

##### **Meteorological Data:**

(The following meteorological data are required for the Gaussian plume model that is used for air transport modeling on the local range. All meteorological data required for European wide transport modeling are included in the *EcoSense* database.)

For each hour of the year a record of the following meteorological data is required:

Flow vector	in [degree] (wind from north = 180°, wind from east = 270°)
Wind speed	in [m/s]
Ambient temperature	in [K]
Stability class	
Rural mixing height	in [m]
Urban mixing height	in [m]
Wind profile exponent	Vertical potential temperature gradient in [K]

*Nuclear power plant***Normal operation:**

Annual electricity generation	in [TWh/a]
Annual release of	
Kr-85	in [TBq/a]
total noble gases	in [TBq/a]
H-3	in [TBq/a]
C-14	in [TBq/a]
Iodines	in [TBq/a]
Particulates	in [TBq/a]

**Simplified accident consequence assessment:***Core inventory:*

Noble gases	in [Bq]
Iodines	in [Bq]
Alkali metals	in [Bq]
Tellurium group	in [Bq]
Alkaline earth metals	in [Bq]
Noble metals	in [Bq]
Metal oxides	in [Bq]

*Release conditions:*

Frequency of occurrence	
Release fraction of core inventory for	
Noble gases	
Iodines	
Alkali metals	
Tellurium group	
Alkaline earth metals	
Noble metals	
Metal oxides	
Starting hour of release after stop of chain reaction	in [h]
Release height	in [m]
Energy release	in [MW]

*Uranium mining and milling*

Fuel chain U <sub>3</sub> O <sub>8</sub> requirement	in [t/TWh]
<b>Uranium mine:</b>	
Annual production of U <sub>3</sub> O <sub>8</sub>	in [t/a]
Annual release of Rn-222	in [TBq/a]

**Mill:**

Annual production of U <sub>3</sub> O <sub>8</sub>	in [t/a]
Annual release of	
Pb-210	in [GBq/a]
Po-210	in [GBq/a]
Rn-222	in [GBq/a]
Ra-226	in [GBq/a]
Th-230	in [GBq/a]
U-238	in [GBq/a]
<b>Uranium mill tailings:</b>	
Tailings generation	in [ha/Gwa]
<i>Operation phase:</i>	
Emission rate	in [Bq/m <sup>2</sup> /s]
Release duration	in [a]
<i>Abandoned tailing piles:</i>	
Emission rate	in [Bq/m <sup>2</sup> /s]
Release duration	in [a]
 <i>Reprocessing</i>	
Annual release of	
H-3	in [TBq/a]
C-14	in [TBq/a]
Kr-85	in [TBq/a]
I-129	in [TBq/a]
I-131	in [TBq/a]
Cs-137	in [TBq/a]

## 8.2 Standard functions and Operators in *EcoSense* Formulas

Name	Description
+ - * /	Addition,Subtraction,Multiplication,Division with standard rules
^	Power. Associativity: $a^b^c = (a^b)^c$ , $a*b^c = a*(b^c)$
sqrt()	Square root
sqr()	Square $sqr(x)=x^2$
ln()	Natural logarithm, ln, is the logarithm with base $exp(1) = 2.71828..$
log10()	Logarithm with base 10
exp()	Exponential function
relative(,)	Relative deviation from x due to y. $relative(x,y) = (x-y) / y$
if then else	A special function is "IF expr < = > expr THEN expr ELSE expr". Each expr may be another expression, including IF's. The result is the value of the expr after THEN, if the condition holds. Otherwise, the function returns the value of the expr after ELSE. Conditions other than <, =, and > are not available. Use parentheses, if you want to continue after an if-expression. For example the following construction is allowed: $sqrt ( if x>0 then x else -x ) - 1$
min(,)	Minimum of the two arguments
max(,)	Maximum of the two arguments
theta()	Heaviside function. $theta(x)$ means: if $x \geq 0$ then 1 else 0. This function can be used to include thresholds, for example $„theta(TotalConcentration-0.2)*x“$ yields x if TotalConcentration exceeds 0.2, otherwise the result is 0.
range(,,)	$range(x,a,b)$ means: if x in interval [a,b] then 1 else 0.

You can define your own functions at the beginning of the formula. An expression may be preceded by one or more definitions like

$$\{ funcname(parameter,...) = subst\_expression \}$$

Funcname and each parameter must not be defined yet. You can't even define a function that starts with a known name. "expe(x)" will cause an error at the 'e', since "exp" is a predefined function. Any character is allowed except of "(),+\*-/;" and white space. A name, that starts with a digit can be defined, but not used. Please avoid characters other than A-Z, a-z, 0-9, and \_ (underscore).

Parameters are separated by commas. The list may be empty, but the surrounding parentheses are still necessary.

The subst\_expression may use these parameters like variables. After the `}`, all parameters become invalid. You can reuse these names for another definition.,

From now on up to the end of this expression you can use the function like any other function.

Examples: { invert ( x ) = if x=0 then 0 else 1/x } invert ( max(1.5,Conc) )

{ f(x)=x\*x+1 } { g(x) = f(f(x))-1 } f(g(g(Variable)))

---

**Note** A function definition does not increase evaluation speed. This feature is implemented to increase readability.

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### 8.3 Natural Ecosystems Covered by the Impact Assessment Module ‘Ecosystems’

As part of the ExternE project the Institute of Terrestrial Ecology in Grange-over-Sands, UK, together with the Stockholm Environment Institute in York, UK, have produced maps for nine natural and semi-natural ecosystems on the EUROGRID 100x100 km<sup>2</sup> grid. The following table summarizes the covered ecosystems together with the acronyms used for them. The UN-ECE has derived empirical critical loads for different ecosystems. Ecosystems cannot be unequivocal classified, at least not from landcover datasets. Hence, ITE has selected the relevant empirical UN-ECE critical loads for the nine ecosystems under analysis here (also listed in the following table).

Ecosystem	Acronym	Ecosystem area [km <sup>2</sup> ]	Critical load of nutrient nitrogen [kg/ha/year]
Acid and neutral, dry and wet unimproved grass	ANUG	564510	20-30
Alkaline dry and wet unimproved grass	AUG	226067	15-35
Alpine meadows	AM	58548	5-15
Tundra/rock/ice	TRI	228218	5-15
Mediterranean scrub	MS	82807	15
Peat bog	PB	50601	5-10
Swamp marsh	SM	23551	20-35
Dwarf birch	BPM/ni	1038997	10-15 (nutrient imbalance)
Scots pine			
Spruce and/or fir	BPM/ns		10-25 (nitrogen saturation)
Pine/spruce with oak/birch			
Pine/spruce with birch			
Maritime pine	BPM/gfc		7-20 (ground flora changes)
Stone pine			
Aleppo pine			
Beech	BO/ni	525642	15-20 (nutrient imbalance)
Various oaks	BO/gfc		10-20 (ground flora changes)
Cork oak			
Holm oak			

Source: ITE, SEI, UN-ECE