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RAINS

A Regional Acidification Information And Simulation Model

pc-version 4.0

--- A User's Guide ---

by

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Preface

This guide is written for the new-comer, who does not have any knowledge of the RAINS model , but who either wants to get an overview of the model or wants to run his/her own scenarios. The structure of the model is presented systematicaly from the user's point, and those who are only interested in an overview could omit chapter 2.

The theoritical basis and assumptions in building up the model are not dealt with in detail in this paper. Therefore, those who want to know more details about the modules of RAINS are refered to the papers listed in the reference list of this guide.

Contents

Chapter I. Introduction

1.1 A general introduction to the RAINS model

The Purpose RAINS (Regional Acidification Information and Simulation), developed at the International Institute for Applied Systems Analysis, is designed as a tool for evaluating acidification control strategies in Europe. Attentions have been given to the importance of examining long-term environmental consequences of control strategies and the cost advantages of a cooperative European sulphur-reduction program.

The Usage The model enables the user to view the entire acidification system and understand how the different parts within the system interact under certain energy assumptions and control strategies. The model is currently sulphur-based and contains NOx in the emission submodel only. It deals with pollution generation, atmospheric transport, deposition and environmental impacts such as soil, lake and groundwater acidification.

Due to the facts that SO_2 emissions from natural sources such as volcanoes and marshes are beyond human control and insignificant in comparision with that from the anthropogenic sources, The RAINS model gives considerations to the anthropogenic emissions only.

Anthropogenic emissions have two origins: energy combustion and industrial processes. Among them, energy combustion is identified by the RAINS model as the main cause of sulphur emissions. So the energy consumption assumption is obviously a central assumption in using the model for emission forecasting. As to this, RAINS provides the user with three basic energy pathways (refer appendix 3 for details):

* **The official energy pathway** which consists of official government projections as compiled by the International Energy Agency for Western Europe and the Economic Commission for Europe for Eastern Europe and the USSR.

* **Natural gas scenario** which investigates the possibilities of increased introduction of natural gas in Europe.

* **Maximum feasible reduction** in which it is assumed that all potential emission reduction achievable with today's pollution control technologies are realized in a cost optimal way.

The energy consumption data for these three basic scenarios may be modified by the user externally. The RAINS model contains a program in the ENEM submodel to regenerate new emission files for the modified database.

The relationship between energy consumption and sulphur emissions can be written:

$$\text{(i)} \quad \mathbf{S}_{ijk}(t) = \mathbf{a}_{ijk}(t) * \mathbf{E}_{ijk}(t)$$

Where:

$S_{ijk}(t)$ = total SO2 emissions from fuel type (i) in sector (j) in country (k) at year (t)

$a_{ijk}(t)$ = SO_2 emission coefficient for fuel type (i) in sector (j) in country (k) at year (t)

E $_{ijk}(t)$ = energy consumption produced by burning fuel type (i) in sector (j) in country (k) at year t

From the equation (i), it can be found that the amount of sulphur emissions from combustion are not only related to energy consumption, but also specific to fuel type, economic sector and country. In the RAINS model, 8 fuel types used by 5 economic sectors are identified:

FUELS: Brown coal, Hard coal, Derived coal (e.g. brown coal briquettes and coke), Light oil (e.g. gasoline), Medium destillate (e.g. gasoil), Heavy oil, Gas and Other fuels (e.g. hydro power and nuclear etc).

(note: Gas and other fuels are assumed to produce no sulphur emissions.)
SECTORS: Conversion (e.g. refineries), Power plants, Domestic, Transport and Industry.

Besides energy consumption, fuel type, sector and country, there are other factors (e.g. cleaning measures and technological progresses) that might affect the effective sulphur emissions over time. Therefore, the coefficient **a** is expressed in equation (ii):

$$\text{(ii)} \quad \mathbf{a}_{ijk}(t) = \mathbf{K}_{ijk}(t) * \mathbf{a}_{ijk}(t_0)$$

Where:

K - the effect of emission abatement measures and technological changes (1>**K**>0)

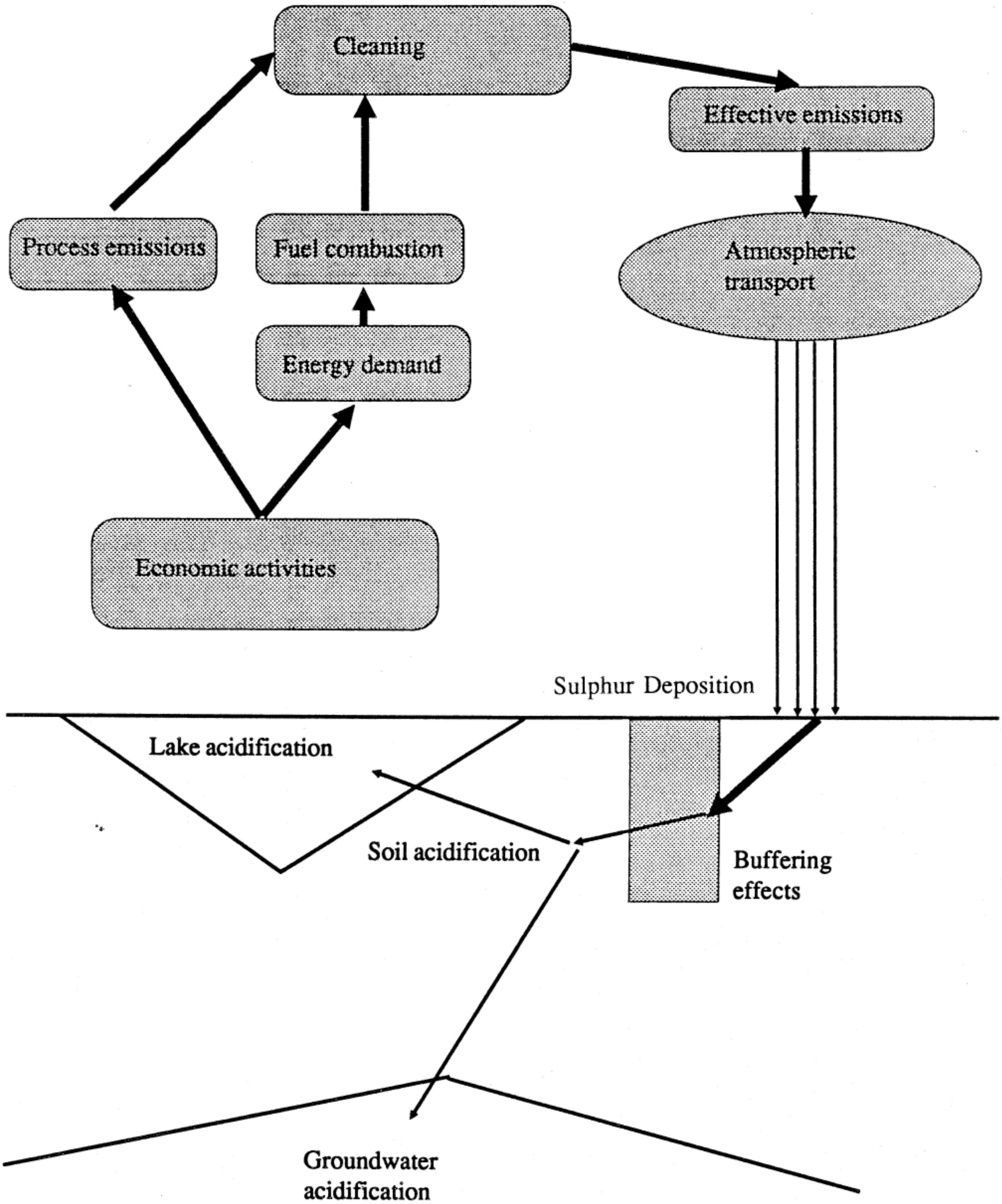
$\mathbf{a}(t_0)$ - base year coefficient

Under certain energy assumptions, the user is given possibilities to affect the effective SO2 emissions by changing the value of coefficient $\mathbf{a}_{ijk}(t)$ through applying various emission control techniques to different fuels and sectors in one or several countries. When **K** = 1, no emission abatement measures are introduced during the period t_0 - t.

Once **E** and **K** are specified, SO_2 emissions to air from energy combustion process can be calculated by fuels, sectors as well as a single country from equation (i). Then the total SO_2 emissions from combustion and that from industrial processes are summed up to obtain country emissions. These calculations are carried out by the SO2 emissions submodel (refer appendix 2 for details).

The atmospheric transport submodel further computes SO2 air concentration and sulphur deposition in Europe due to sulphur emissions in each country, and then sums the contributions

Figure 1. The acidification process



from each country with a background contribution to compute the total sulphur deposition at any grid location (refer appendix 2 for details).

SO_2 deposition is the main cause of soil acidification. The state of soil acidification is measured by pH value in the soil acidification submodel. The module computes the percentage of soil in certain area within user specified pH range. (refer appendix 2 for details).

If the acid deposition is inadequately buffered by soil in the lake's catchment, lake acidification may result. The extent of lake acidification also depends on the amount of snowmelt, flowpaths of runoff and lake chemistry etc. RAINS's lake acidification submodel attempts to provide a quantitative overview of the key processes and produce mean annual lake acidity in user specified pH and alkalinity classes in a country. At present data for only three countries (Finland, Norway, Sweden) are available (refer appendix 2 for details).

The whole process described above is depicted in figure 1 .

1.2 Applications and limitations

The RAINS model is used basically in two ways:

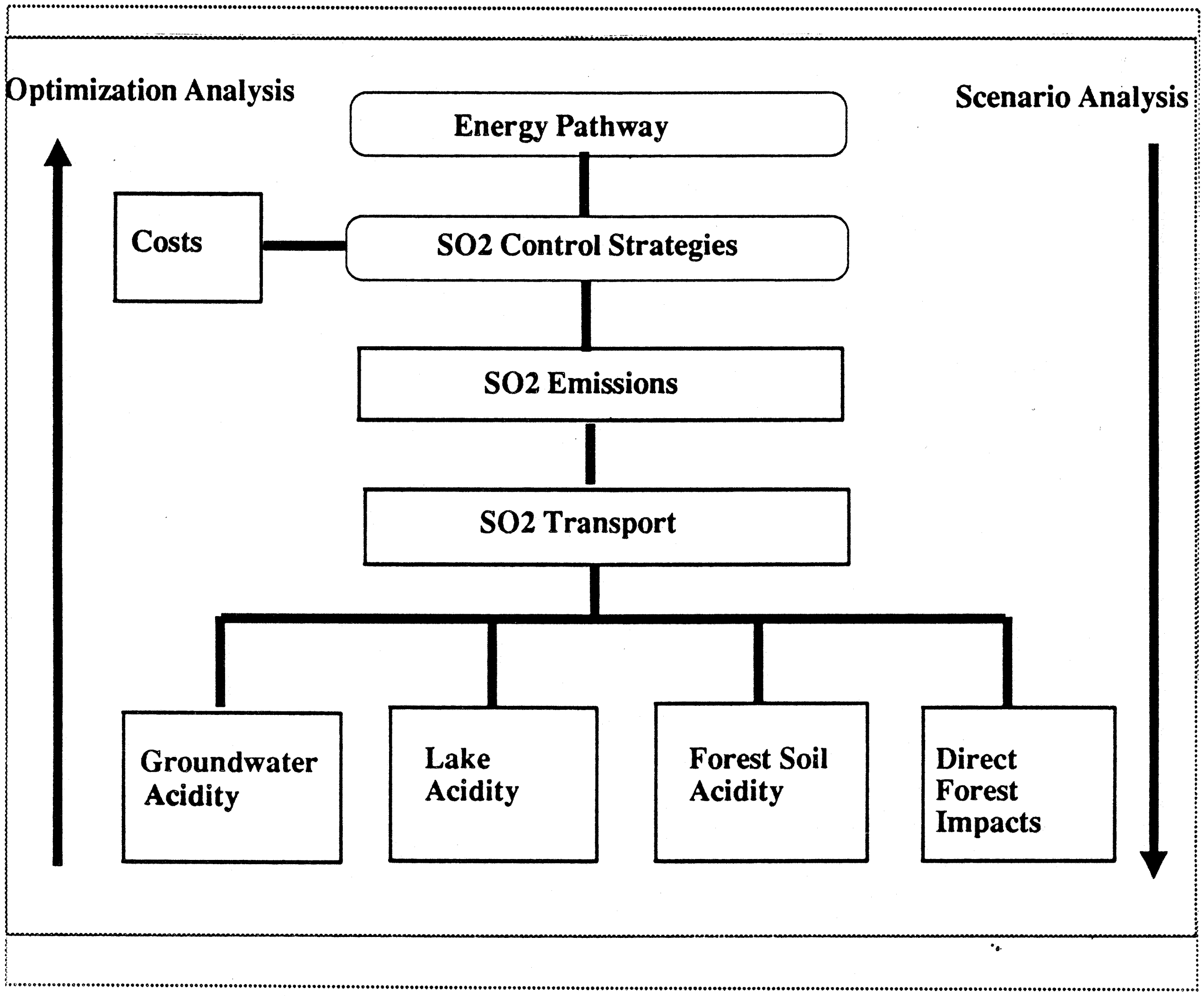
* Scenario analysis
* Optimization analysis

To conduct scenario analysis, the user essentially moves from top to bottom through the model as depicted in figure 2. The user first specifies an energy pathway and/or a control strategy, and then has the possiblities to examine all the outputs from any of the submodels.

In optimization analysis, the user inverts the scenario analysis procedure by starting with the environmental goals to determine a cost effective scenario, that is, optimal sulphur control strategy.

The function of optimization analysis, and the scenario analysis for groundwater and direct forest impact are not yet available in the RAINS PC-version 4.0. .

Figure 2. A schematic overview of the RAINS model

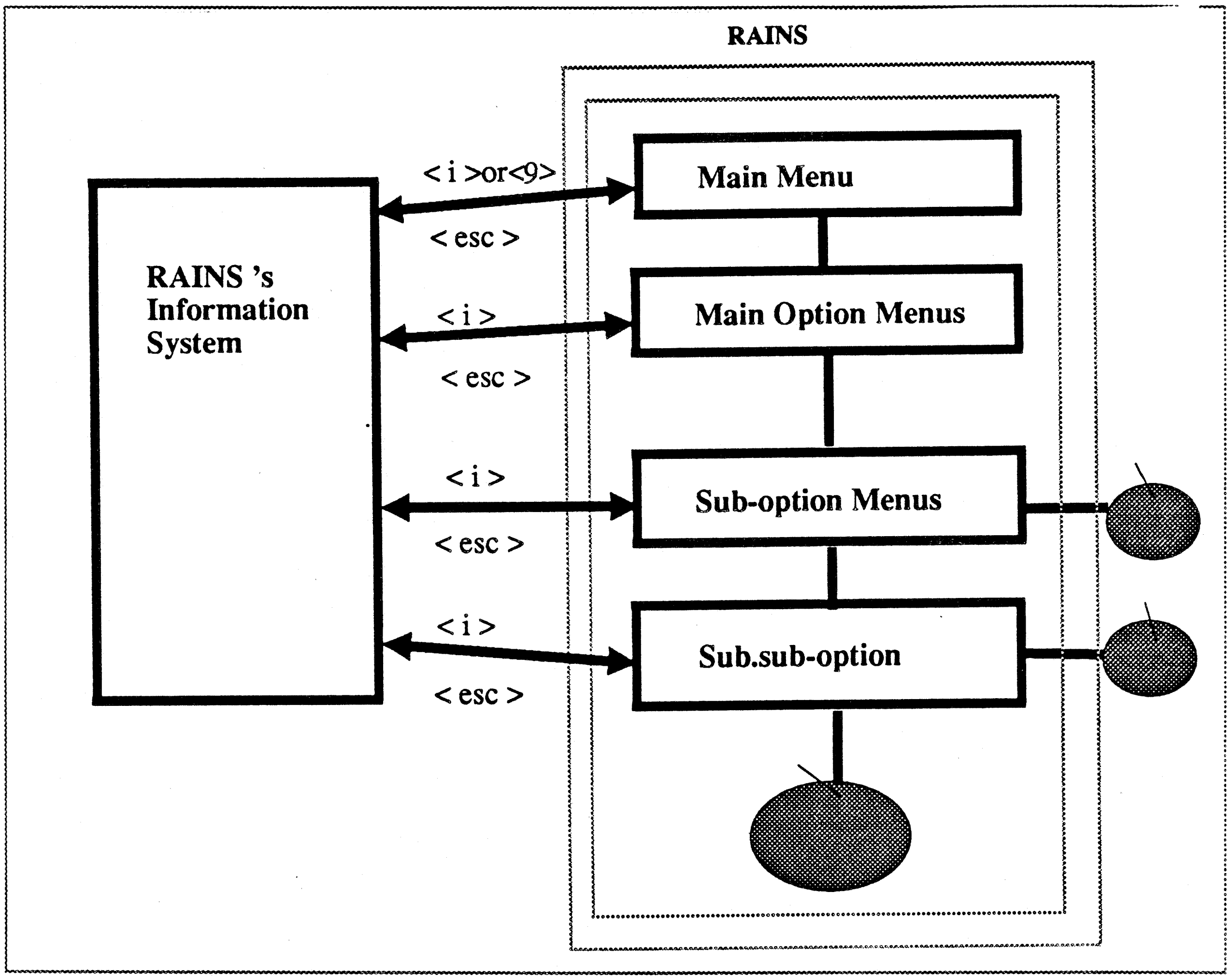


Chapter II. Symbols and Commands

2.1 The information system

It would be helpful for new users to know the information system before starting RAINS. The information system in the RAINS model is comprehensive and is available from the main menu and every submenus as indicated in figure 3. When executing the information function, the user is given detailed description on the user specified options.

Figure 3. Communication between RAINS's submodels and its information system

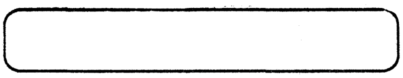


The commands leading to the information system are in every menus following the main options. To inquire about a certain option, the user types a single character <i> followed with the option number. To ask for scenario information, the user types <8> from the main option menu of

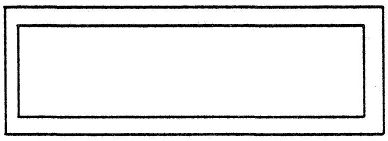
ENEM submodel. By pressing the < esc >key, the user exits the information system and returns to the previous menu.

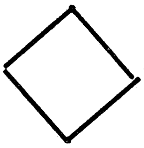
2.2 Symbols used in the guide

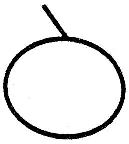
In order to help the user consulting the guide more effectively, the symbols used in rest of this guide are listed here.

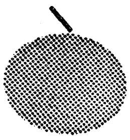

text descriptions

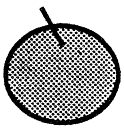

submodels

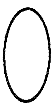

model

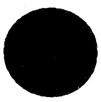

optional point


final output (table only)


final output (graphic only)


final output (table and graphic)


connecting point


formulation of new scenario

2.3 How to give commands

The commands that are acceptable to the program are limited to those in the command lists. There are two types of command lists the user may encounter in RAINS.

Type 1: The user finds the commands contained in RAINS's menus. They can be numerical numbers as well as single letters. To give commands from type 1 list, the user types the number or the single letter as indicated in the menus.

Type 2: When the user is in a operational state within the module, he/she encounters another type of command list which stands on the bottom of the screen. An example of this type of commands list is shown in figure 4.

Figure 4. The commands list - type 2

```
                 **************************

                 *************************

                 *************************

<down>  <up>  <Undo>  Space = <select>     CR = <ready>
```

To give commands from the type 2 list, the user types merely the first character of the commands in the command list, e.g. type <d>/<u> to move the cursor down/up the row. But for those commands at the right hand side of equations, the user hits the keys indicated at the other side of the equations, e.g. to select country/year/energy pathway, press space bar.

The results from RAINS can not be printed directly from the program, but all the 4 ranges of outputs (except graphics) from RAINS's 4 submodels can be dumped automatically into 4 dos files named "enem.prt", "dep.prt", "soil.prt" and "lake.prt" respectively by typing < p >. These files are cleared every time the RAINS system is started, therefore **remember to make a copy if the contents is expected to be preserved or printed later.**

RAINS program distinguishes upper and lower case characters in reading commands.

Chapter III. The RAINS model

3.1 What RAINS offers? - The output list

RAINS offers the user four ranges of products which are produced from RAINS's four submodels:

(1) **range 1 - energy, emission and cost**
(a) view energy database
(b) SO_2 and NOx emission calculations
(c) abatement cost calculations

(2) **range 2 - SO_2 deposition calculations**

(3) **range 3 - the state of soil acidification**

(4) **range 4 - the state of lake acidification**

These products are listed in more detail in the output list (refer appendix 1).

3.2 How is RAINS structured? - The apple tree

The structure of RAINS is depicted by an upside-down apple tree (see figure 5). The user may first check the output list to find out what products he/she needs and the addresses that describe their locations on the apple tree, then starts from the root (the main menu) and go downwards along the branches, guided by the address, until he/she reaches the wanted products. Every apple represents a single output from RAINS (listed in appendix 1).

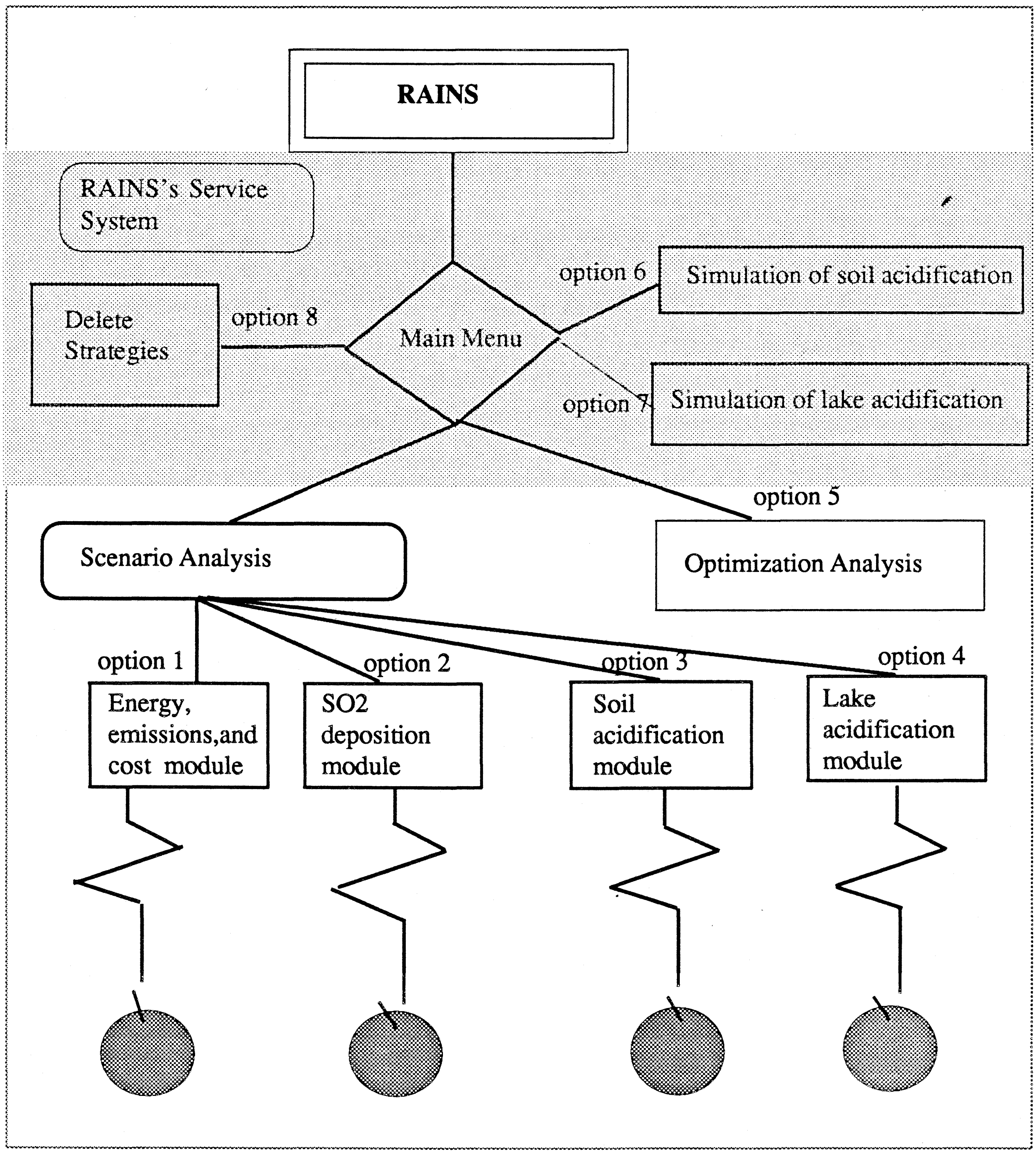
Refer figure 5.

3.3 Where are the entrances?

The user has by now a general idea about the organization of the RAINS model. The next step is to find the entrance to the program.

From an operational point of view, there is only a single way to enter RAINS, that is, starting from the main menu at the root of the tree. But logically, the user has two entrances depending on which energy pathways and/or control strategies he/she is going to employ. The user enters from the main menu when making use of existing scenarios. But a more active way of using the program is to examine the environmental effects of the user designed scenarios. In this case, the user has to begin with creating new scenarios by applying various control techniques to fuels, sectors or countries, or directly restrict maximum emission levels. The next two sections will deal with the details of the two types of entries.

Figure 5. The apple tree



3.4 Entrance one: employing the existing scenarios

After having decided to use the established scenario assumptions (refer appendix 2 for scenario information), the user has 4 alternatives from the main menu which lead to 4 submodels:

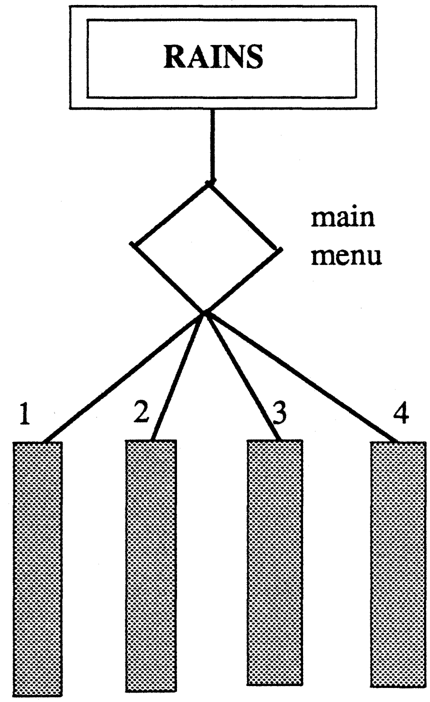
Alt 1: Energy, emission and cost module

Alt 2: SO2 deposition module

Alt 3: Soil acidification module

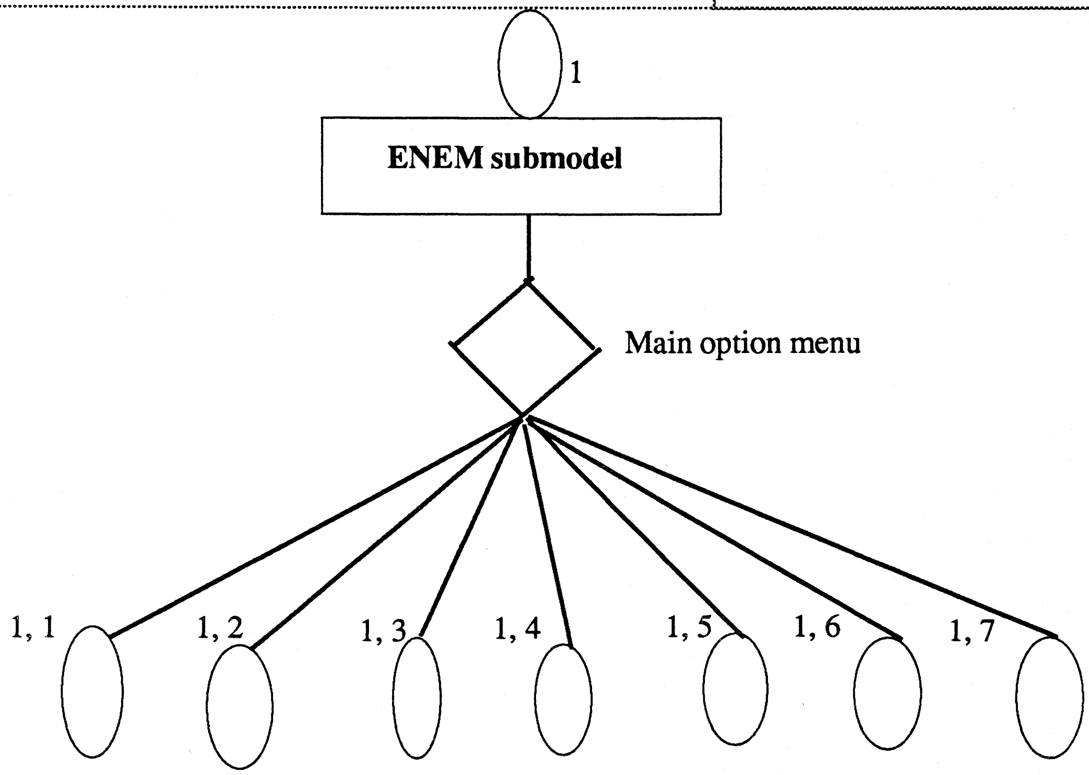
Alt 4: Lake acidification module

Figure 6. From the main menu to the 4 submodels



3.4.1 The energy, emission and cost (ENEM) module

Figure 7. Main options of ENEM submodel

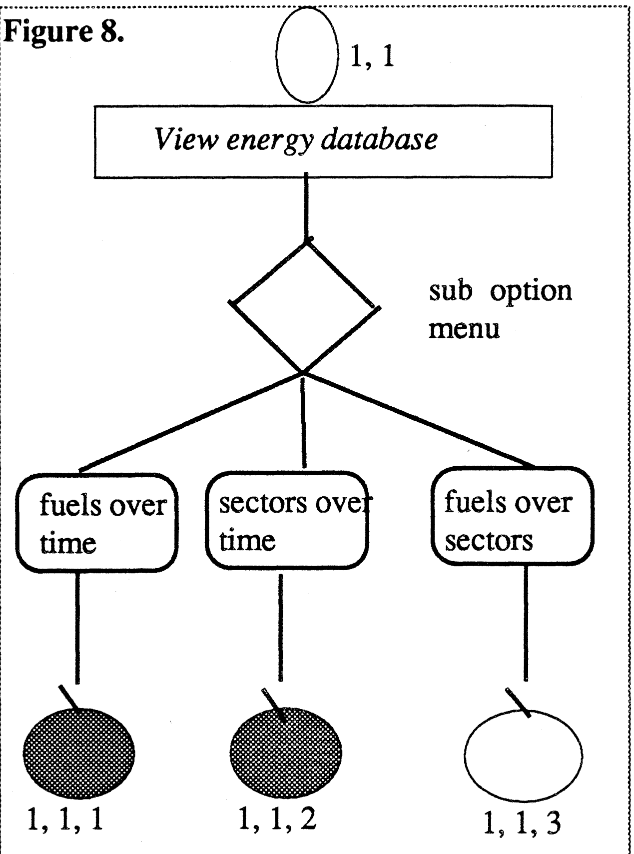


The major role of the ENEM submodel is to present spatially the anthropogenic emissions of acidic precursors which is the main cause of acidic deposition. In this module, the user has the possibilities to (see figure 7):

(1) *view the energy database* for established scenarios. These data are the basis for all the calculations being carried out later by other three modules.

In this function, ENEM provides the user with energy consumption statistics in three forms (figure 8):

Figure 8.



Form 1 (fuels over time) is the list of the amount of energy consumed through each of 8 fuel types for all reference years (1960-2000) for one or a group of countries. The data can be displayed by table and graphic (address 1,1,1)

Form 2 (sectors over time) is the list of the amount of energy consumed in each of 5 economic sectors for all reference years (1960 - 2000) for one or a group of countries. Table and graphics. (address 1,1,2)

Form 3 (fuels over sectors) is the table list of the amount of energy consumed in each of 5 economic sectors through each of 8 fuel types for a selected time period for a country or region. (address 1,1,3)

(2) *view SO2 emissions calculation*

The purpose of this function is to present the temporal and spatial variability in SO2 emissions at the country level once a future energy scenario is selected.

SO2 emissions from a single country can be displayed

(a) by fuel type over time (address 1,2,1).

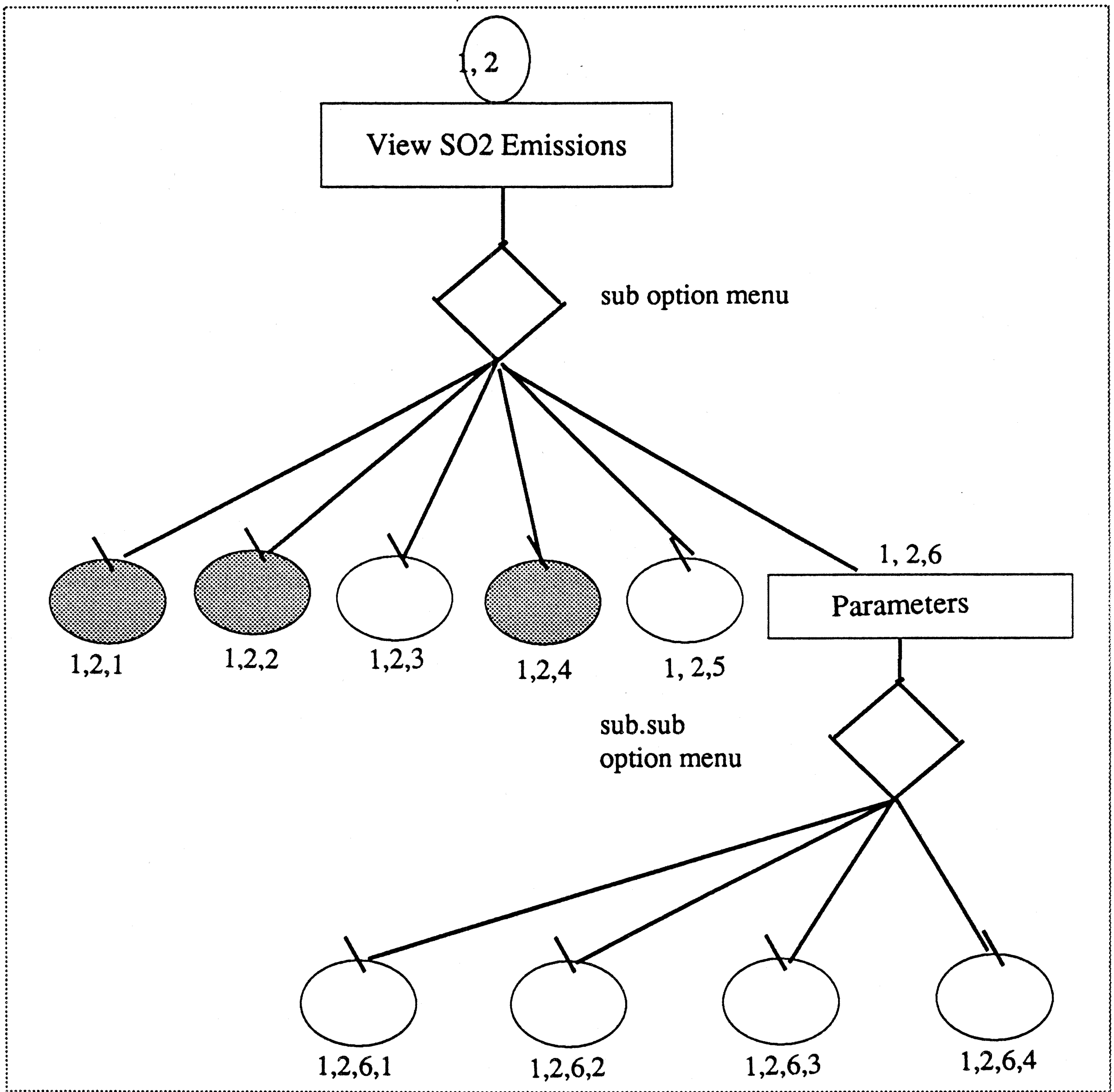
(b) by economic sectors over time (address 1,2,2).

(c) by fuel type over economic sectors for one reference year (address 1,2,3).

(d) in total SO2 emissions of each country over all reference years for all the countries in Europe (address 1,2,5).

Emissions from two different scenarios can be compared by choosing option 4 from the sub-option menu (address 1,2,4).

Figure 9.



Finally, option 6 enables the user to view the parameter values that were used to perform the SO_2

emission calculations. There are 4 groups of data available to the user and these parameters are assumed constant over the whole time period:

* The emission factor which is defined as the mass of SO_2 emissions per unit of energy consumed without any control, e.g. the value of coefficient **a** when **k** = 1 in equation (ii) (address 1,2,6,4). In RAINS, the emission factor is derived from the three other parameters below.

* Fraction of sulphur retained in the ash. This parameter is specific to fuel type and applied to all countries (address 1,2,6,3).

* Heat values of fuels = f(fuel type, country). (address 1,2,6,2).

* Sulphur content = g(fuel type, economic sector, country).(address 1,2,6,1).

(3) *view NOx emissions calculation*

The purpose of this function is to calculate the temporal and spatial variability in NOx emissions at the country level once a future energy scenario is selected. NOx emissions can not be calculated in the same way as sulphur emissions because they originate not only from nitrogen in fuels but also from nitrogen in air. RAINS avoids these complications by deriving sector and fuel-specific NOx emission factors from a regression of emissions on fuel use per sector which are applicable to many countries. The NOx emission factor is defined as the mass of NOx emissions per unit of energy used and is accessable from address 1,3,6.

The NOx emission results are displayed in the same way as SO2 emissions from addresses: 1,3,1. 1,3,2. 1,3,3 and 1,3,5. The comparision of two scenarios is also possible in address 1,3,4.

(4) *view cost calculation*

The cost submodule concerns the direct abatement costs at the country level for a given energy scenario. The indirect costs and benifits such as unemployment and improved visibility are not given consideration in the RAINS model (refer appendix 2 for details).

In the case of using the existing energy scenarios, the first two basic scenarios (official energy pathway and natural gas scenario) are assumed no abatement measures. Therefore the costs for these two scenarios are always zero for every country.

The SO2 abatement cost data for a control strategy in a single country are available by

(a) fuel type over time (address 1,4,1)

(b) economic sector over time (address 1,4,2)

(c) fuel type over economic sector for one reference year (address 1,4,3)

The next two options enable the user to compare the abatement costs of two scenarios (address 1,4,4) and view the abatement cost of one scenario for all countries for a certain time period (address 1,4,5).

In the 6th option (address 1,4,6), the user can review the parameter values that were used to perform the cost calculations. The main parameter required to estimate emission control costs is the cost coefficient defined as the direct cost of SO_2 emission reductions either per unit of energy consumed or per mass of SO2 removed (addresses 1,4,6,1 & 1,4,6,2).

cost coeff. = y(fuel type, plant age, economic sector, country)

There are 5 other parameter types that influence SO_2 emission reduction costs available to the user from address 1,4,6,4 to 1,4,6,7. These values are applicable to all energy scenarios for all countries at all the time periods.

The last option in the cost submodule is the national cost curve. This option will provide table and graphic display of the SO2 emissions masses after installing the optional control techniques. The cost function gives the cost optimal ranking and the removal potential of control options for further control beyond the already specified measures of the scenario (address 1,4,7)(refer exercise task2).

Option 5 and 6 in the ENEM main option menu will be dealt with in the section 3.5 "Entrance two - employing existing scenarios".

Option 7 in the ENEM main option menu will be dealt with in section 3.6 "the service system".

Examples

Task 1:

View energy consumption data by sectors over time for Norway at the assumption of official energy pathway.

Operations:

Step	purpose	the keys used
1	enter from RAINS main menu	hit <1> <1> <2>

2 select country and energy pathway <space bar><CR>

The output table

```
          _RAINS    ENEM VERSION 4.0 (1. May 1988)        (C) IIASA
ROUTE:12000000                                      printed on   08/0

Official Energy Pathway
@N

                ENERGY_USE_PER_SECTOR   (PJ)
```

	1970	1975	1980	1985	1990	1995	2000
CON	33	48	90	122	130	120	104
PP	153	208	226	286	305	324	343
DOM	93	106	192	168	202	270	289
TRA	103	118	144	136	153	169	181
IND	243	263	306	312	311	328	346
OTH	26	28	61	59	52	54	57
SUM	655	773	1021	1085	1154	1269	1323

3 print the table hit <p>

4 view graphic output hit <g>

Task 2: View the national cost curve of Norway in year 2000 under the Official Energy Pathway.

Operations:
From address 1,4,7, the user may get the output as:

```
              _RAINS    ENEM VERSION 4.0  (1. May 1988)
ROUTE:47000000

SCENARIO:        Official Energy Pathway

                    "SEGMENTS OF THE NATIONAL COST FUNCTION@

              _TECHNOLOGY   EMISSION      COST@
              "UNABATED  @       141          0
              "HF-IND-LS @       136          4
              "HF-PPn-LS @       136          4
              "HF-DOM-LS @       136          5
              "HF-PPo-LS @       136          5
              "HF-CON-RP @       132         13
              "HF-IND-RP @       130         18
              "HC-CON-FGD@       127         26
              "HC-IND-RP @       116         58
              "HF-IND-FGD@        95        126
              "PROCESS-#1@        76        219
              "DC-IND-RP @        71        265
              "PROCESS-#2@        52        451
              "HF-PPn-FGD@        52        455
              "HF-PPo-FGD@c       51r       457
              "PROCESS-#3@u       39n       705
```

The table lists the cost optimal combinations of SO2 abatement technologies applying to 8 fuel types in 5 economic sectors plus process control at certain left-over SO2 emission level. In the case of no abatement measures, the SO2 emission level will reach 141 kilotons sulphur from Norway in year 2000 under official energy pathway. If the emission level should be reduced to 132 kilotons sulphur, the cost optimal abatament strategy is to apply regenerative process techniques to heavy oil in the conversion sector (e.g. HF-CON-RP). This control measure will cost 13 million DM. (refer appendix 4 for the meanings of the abbreviations).

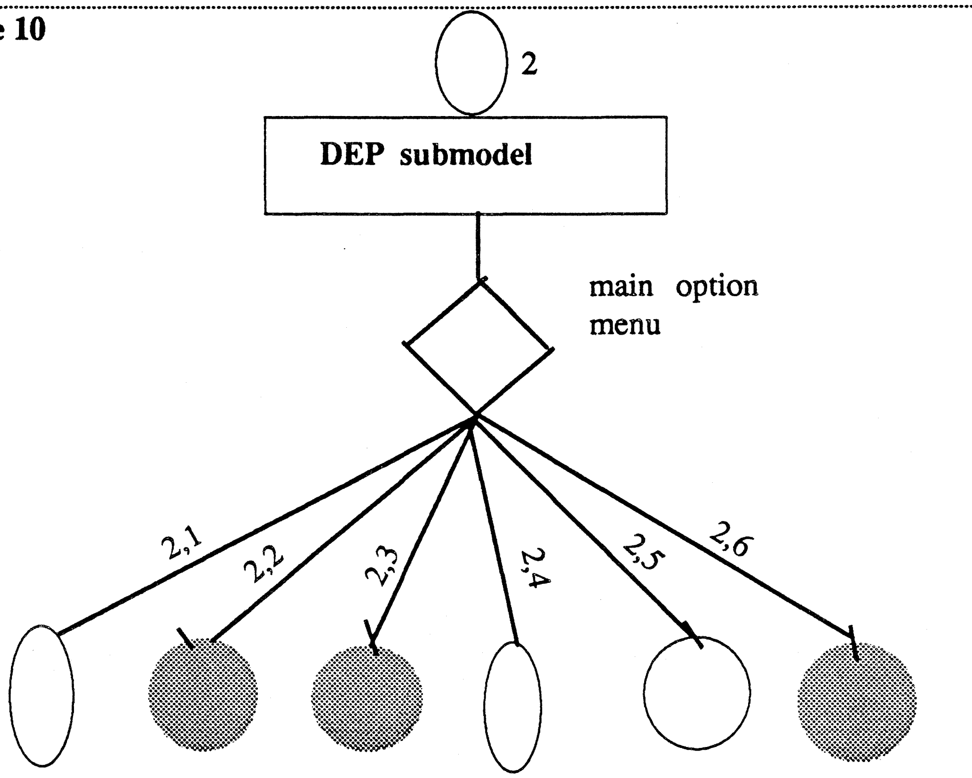
3.4.2 Transport and deposition (DEP) module

The importance of the DEP module stems from its role in linking, through the long-range transport model EMEP, anthropogenic emission sources to the net amount of acidic deposition.

When entering this module, the user has 6 main options from the main option menu:

See Figure 10.

Figure 10



(1) Option 1 (address 2,1) - deposition isolines due to a group of countries for a specific year.

In this option, there are three possibilities:

* display of isolines for one scenario (address 2,1,1)

* comparision of isolines for two scenarios (address 2,1,2)

* display of isolines and their uncertainty range (address 2,1,3)

The last choice displays an uncertainty range of 25% around the isolines of one scenario. The types of uncertainties considered are listed in the table below:

Table 3. Comparison of uncertainties in the EMEP model.

Type of Uncertainty	Uncertainty of Computed Sulfur Deposition*	Notes
Non-linearity	± 27%	Bias error based on model experiments with non-linear wet deposition coefficient
Geographic distribution of emissions	± 18%	90% confidence interval due to ± 50% range of grid emissions
Interannual meteorologic variability	± 32%	Mean relative deviation for 4 meteorologic years
Parameter estimation	± 25%	90% confidence interval due to 30% parameter range

* At Illmitz Austria due to emissions from German Democratic Republic, 1980 meteorological conditions

(2) Option 2 (address 2,2) - comparision of 2 isoline values for 2 years.

(3) Option 3 (address 2,3) - evolution of 1 isoline value for up to 6 years.

(4) Option 4 (address 2,4) - time evolution of an area with a deposition level above certain given values.

In this option, the user can choose either to display percentage of area for one scenario (address 2,4,1) or to display percentage of area comparing two scenarios (address 2,4,2).

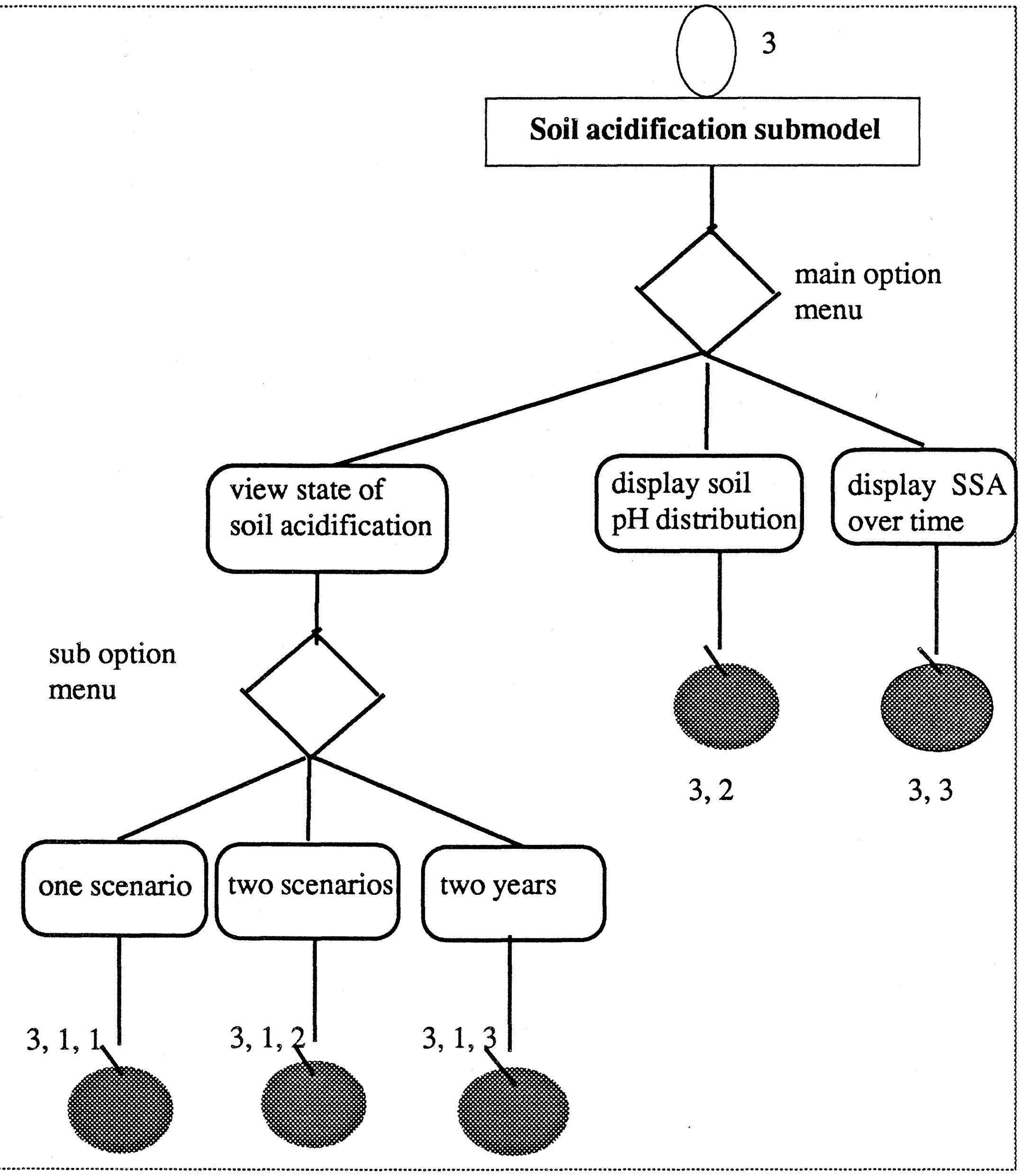
(5) Option 5 (address 2,5) - deposition at a specific location due to a group of countries.

(6) Option 6 (address 2,6) -colored deposition pattern due to a group of countries for a specific year.

3.4.3 Soil acidification module

The soil acidification module provides information on the state of acidity of forest soils in a multistate region for a selected scenario in a chosen reference year. When using this module for the basic scenarios, the user has direct access to three main options:

Figure 11.



(1) Option 1 (address 3,1) - display the state of soil acidification (SSA) .

In this option, the user is further provided with three possibilities.

(a) to view the SSA for only one scenario in a reference year (address 3,1,1).

(b) to compare SSA with another scenario in a certain year (3,1,2).

(c) to compare SSA with another year for a certain scenario (address 3,1,3).

(2) Option 2 (address 3,2) - display areas with soils below a certain pH.

(3) Option 3 (address 3,3) - display time evolution of forest area below a certain threshold value.

The user can select acidification indicators among:

* pH

* base saturation

* Ca/Al ratio in soil solution

* Ca/Al ratio in fine roots

* Al3+ concentration

3.4.4 Lake acidification module

The lake acidification module displays lake chemistry in a multistate region for a selected scenario in a chosen reference year for Finland, Norway and Sweden. In the case of using existing scenarios, the user has direct access to two main display options, and there are subsequently three suboptions in each main option.

(1) Option 1 (address 4,1) - display the mean annual lake pH distribution for a defined region.

Choosing this option, the user can either look at pH distribution for a simulated scenario (address 4,1,1), compare pH distribution of one scenario with that of another (address 4,1,2) or compare pH distribution of one year with that of another year for certain scenario (address 4,1,3).

(2) Option 2 (address 4,2) - display the mean annual lake alkalinity distribution for a defined region.

This option eables the user to perform the same type of analysis as in option 1 to examine alkalinity distribution (from address 4,2,1 to 4,2,3).

Example:

Task: look at pH distribution of Norwegian lake area in year 2000 under the official energy pathway.

Operations:

Steps	Purpose	Keys used
1	enter lake module from RAINS's main menu	hit <4><1><1>
2	select energy pathway	<space bar><CR>

(note: if the scenario does not appear on the screen, the user should leave this module to RAINS's main menu and run option 7 for that specific scenario)

Steps	Purpose	Keys used
3	select country	<space bar><CR>

(note: if the desired Fennoscandian country does not appear on the screen, the user must exit the present module to RAINS's main menu and run option 6 for that particular scenario and country)

Steps	Purpose	Keys used
4	select period	<space bar><CR>

output table:

```
                    VERSION 4.0 (1. May, 1988)
ROUTE:12000000                      (C) IIASA@            PAGE   1
                                    printed on   22/08/89
Official Energy Pathway

State of lake-acidification                  Norway        2000
     % of Lakes within pH classes per Lake Region
                 COUNTRY
                 <    5.3 > pH  >     6.3

          1        87.1     12.9      .0
          2        37.4     46.3     16.4
          3        13.9     61.8     24.3

        SUM        46.1     40.3     13.6

          TOTAL REGIONAL DISTRIBUTION:     46.1     40.3     13.6
```

The program supplies automatically pH criteria values as 5.3 and 6.3. The first and third columns display the percentage of lakes within a district having pH values less than the lower pH criterial value and greater than the higher criteria value respectively. The middle column includes those lakes whose pH values lies between the two set criteria values. Each country is divided into districts (Finland 5, Sweden 6 and Norway 3) that are represented by the number at first of each row. If the user wants to examine the situation with different criteria values, he/she can enter the new values at the same place as the old ones stand and press <c> to calculate new distributions.

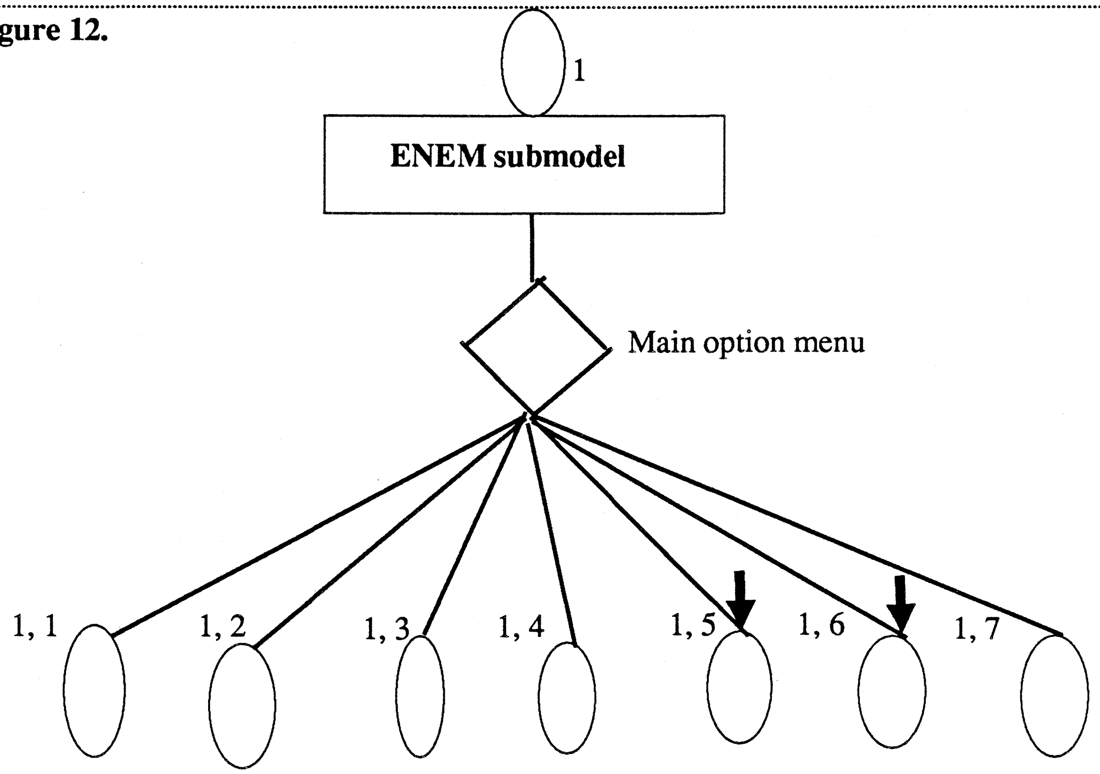
5	view graphic output	hit <g>

3.5 Entrance two: Creating user's own strategies

After having got acquainted to RAINS's structure and operations with the basic scenarios, the user should try to use the program by entering from the second logic entrance.

This important entrance is located within the ENEM submodel, and consists of option 5 and 6 in its main option menu as indicated in figure 12.

Figure 12.



* option 5 - execute control strategies (address 1,5)

* option 6 - execute direct input of SO2 emission (address 1,6)

Choosing option 5 or 6 in the ENEM main option menu, the user can design his own strategies by either employing any combination of existing SO2 reduction techniques based on existing energy database or directly inputing SO2 emission limitations. Once saved, the new scenario will be listed with other existing scenarios. Then the user may exit from the ENEM submodel to RAINS's main menu, and examine every output from the 4 submodels for the created scenario like the basic scenarios described above.

3.5.1 Execute control strategies

There are basically 4 ways to reduce sulphur emissions originating from energy combustion:

(a) energy conservation

(b) fuel substitution

(c) use of low sulphur fuels

(d) desulphurization which includes combustion modification, fuel gas desulphurization and regeneration process.

Since goals other than pollution control may motivate energy conservation policies, RAINS does not contain formal procedure to estimate its SO_2 reduction potential and related cost as it does for the other three methods. In formulating new strategies, the user may employ combination of (b), (c), (d) and process control techniques.

In this option, the user can choose whether to carry out a country specific SO2 abatement plan (address 1,5,2) or to have a global SO2 abatement agreement (address 1,5,3).

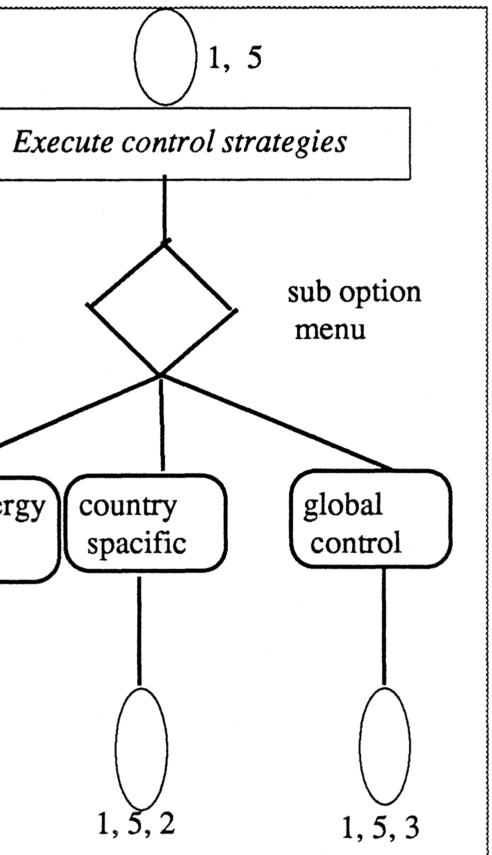
Refer Figure 13.

The user has the option to consult energy consumption figures per fuel and sector (address 1,5,1) during considering various control strategies.

(1) *country specific SO2 abatement* (address 1,5,2)

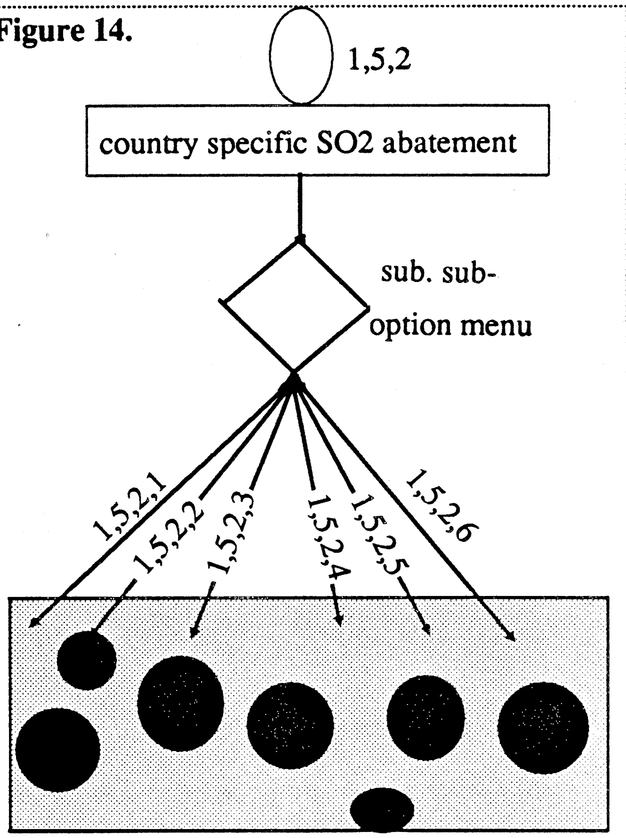
Once choosing the country specific abatement strategy, the user has the possibilities to apply different SO_2 emission abatement techniques to various economic sectors. These suboptions are (refer figure 14):

Figure 13.



control technique	**apply to:**	**address**
fuel switching	powerplants	1,5,2,1
fuel switching	industry, domestic	1,5,2,2
direct control	powerplants	1,5,2,3
direct control	industry	1,5,2,4
direct control	conversion, domestic and transport	1,5,2,5
process emission control		1,5,2,6

Figure 14.



As mentioned, the user may utilize one or more options to formulate a scenario.

(2) *global SO2 abatement option* (address 1,5,3)

Besides country specific control, the user can allocate any control technique to any sector or fuel type which is applied universally to a multistate region.

This selection provides the user with 4 groups of economic sectors to which the control techniques are supposed to apply for a global abatement strategy.

Suboption	**sectors**	**address**
1	powerplants	1,5,3,1
2	industry	1,5,3,2
3	conversion, domestic and transport	1,5,3,3
4	process emission control	1,5,3,4

The user may utilize one or more options to formulate a scenario.

Examples:

Task : formulating a country specific strategy.

To use fuel switching technique in the Polish industrial and domestic sector. Switching from coal and oil to electricity (ELE) and other fuels (OS).

Operations:

STEP	PURPOSE	KEYS
1	enter ENEM module from	
	RAINS main menu	hit<1><5><2><2>
2	select country (Poland)	<space bar><CR>
3	select a root scenario the control measure is based on	
	(official energy pathway)	<space bar><CR>
4	select year (2000)	<space bar><CR>

Table appears (see next page).

Table indicates energy input to both the industrial and domestic sectors through 8 applicable fuel types plus district heat. Combustion efficiency are adjacent to the fuel input values so that annual energy supply can be calculated for each fuel type.

SO2 and NOx emission figures and the costs associated with the root scenario are presented in the table before any reallocations.

The user may try to reallocate any fuel input value either to industry or domestic to reduce sulphur emissions and satisfy energy demand concurrently.

STEP	**PURPOSE**	**KEYS**
5	choose to change fuel input	hit <c>
9	input new data	type new data

_RAINS ENEM VERSION 4.0 (1. May 1988)
ROUTE:52200000 (C) IIASA PAGE 2
printed on 08/08/89

Official Energy Pathway Poland 2000
Control Strategy: FUEL SUBSTITUTION -
INDUSTRY and DOMESTIC

	INDUSTRY			DOMESTIC			
	Fuel Input [PJ]	Comb. Effic [%]	OUT-PUT [PJ]	Fuel Input [PJ]	Comb. Effic [%]	OUT-PUT [PJ]	
BC	(.0)	50.0	.0	(.0)	40.0	.0	
HC	(101.1)	60.0	60.7	(1305.0)	40.0	522.0	
DC	(214.9)	70.0	150.4	(135.0)	40.0	54.0	
MD	(56.0)	70.0	39.2	(189.0)	50.0	94.5	
HF	(104.0)	70.0	72.8	(.0)	55.0	.0	
NG	(357.0)	70.0	249.9	(140.0)	50.0	70.0	
OS	(.0)	50.0	.0	(60.0)	40.0	24.0	DEMAND
ELE	(370.0)	95.0	351.5	(175.0)	95.0	166.3	575.0
DH	(900.0)	80.0	720.0	(275.0)	80.0	220.0	1175.0

FINAL DEMAND covered:	1644.5	NATIONALTOTALS:	1150.7	SUPPLY
original scenario:	1644.5	SO2 4038.9	1150.7	625.1
		NOx 1385.5		1175.0
		COSTS .0		

RAINS may respond with signal to warn that the final demand, electricity demand or district demand balance is violated. In this situation, the user has 4 options:

(1) to ignore the warning if other values will be changed to compensate the balance.

(2) to undo (delete) the change the user just made

(3) to fit the balance with value automatically filled by RAINS

(4) to change the new input to another value.

The columns for SO_2 and NOx emissions and costs will change automatically with every new change made by the user. Once finished, these values represent the emission and cost data associated with the new scenario.

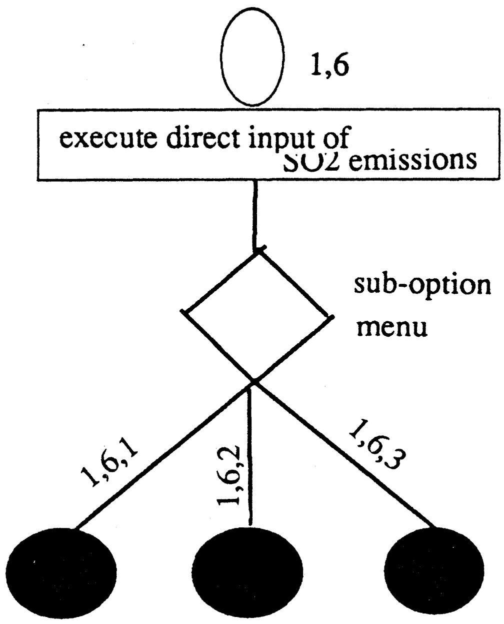
10	save new scenario	hit <s>
11	name new scenario	type "exercise"

3.5.2 Execute direct input of SO2 emissions

This option enables the user to input the abosolute SO2 emission numbers for each country (address 1,6,1), or input percentage of 1980 emission value for each country (address 1,6,2), or input percentage of 1980 emission figure for all countries (address 1,6,3) as shown in figure 15.

A new scenario can only accept the inputs from one of these options. The scenarios created by direct input of SO2 emission will be considered as "emission only" scenarios which are not applicable to cost and fuel, sector specific calculations.

figure 15.



Example:

Task: creating a scenario with SO2 emission restriction in year 2000 as 50% of that of 1980 from Poland, F.R. of Germany, root scenario is official energy pathway.

Operations:

Enter the right branches by pressing < 1 >, < 6 >, < 2 > at each optional point, then input new SO_2 emission values for Poland and F.R.of Germany as 50% of that of 1980 at year 2000 as indicated in the table below:

INPUT_OF_USER_SPECIFIED_SULFUR_EMISSIONS

[in % of 1980 emissions]

COUNTRY	1985	1990	1995	2000	COUNTRY	1985	1990	1995	2000
L	137	146	153	158	AL	100	149	174	199
NL	70	93	99	105	A	83	91	95	100
N	90	89	100	102	B	68	70	70	70
PL	100	90	94	50	BG	99	132	136	141
P	103	107	121	132	CS	97	84	79	74
R	95	136	145	155	DK	85	90	90	91
E	96	98	101	101	SF	82	79	75	75
S	92	72	74	76	F	64	54	51	47
CH	78	74	81	81	D	93	87	88	50
TR	116	180	233	279	DDR	94	96	97	97
UK	89	91	89	88	GR	122	193	234	273
SU	104	104	102	99	H	93	78	86	94
YU	99	178	218	258	IRL	68	90	104	117
					I	82	88	83	77

Save the scenario as " EX3"

3.6 The service system of RAINS

RAINS's service system contains option 6, option 7, option 8 in the main menu and option 1,7 in the ENEM main option menu (see figure 5).

The service system does not produce table or graphic output but prepares data for calculations in all modules and delete unwanted strategies.

3.6.1 File maintenance (address 1,7)

This option performs three service functions:

(a) generate emission files which is necessary if the energy database of a basic scenario (official energy pathway, natural gas scenario or maximum feasible reduction) be modified externally.

(b) generate binary datafile which updates the necessary data structure after an external change of cost data or emission parameters.

(c) dump cost function files which puts the cost functions of a specific scenario and year to disc for future use within ENEM or for data transfer to the optimization module.

3.6.2 Simulation of soil acidification (address 6)

After the user created an abatement strategy, he/she will only be able to view the results of this strategy in terms of soil acidification after the soil acidification module is executed for that specific scenario. It takes about 10 to 20 min. of real time to execute this module.

3.6.3 Simulation of lake acidification (address 7)

Likewise, this module has to be executed before the user is able to view the results of any new strategy in terms of lake acidification. It takes about 10 to 20 min. to execute this module.

3.6.4 Delete strategies (address 8)

When the user wants to delete existing strategies, chose option 8 from the main menu. The three basic scenarios can not be deleted.

Once entered this option, the user does not have the chance to regret. At least one strategy have to be deleted.

3.7 scenario analysis - Examples

The intention of this section is to assemble all the fragmented information presented in the previous three chapters and to create in the user's mind a complete framework of scenario analysis.

two cases are presented and all the important steps in carrying out the scenario analysis will be listed:

<u>Example 1:</u>Creating a scenario in which Poland and F.R.Germany jointly carry out a SO2 reduction plan to restrict the SO2 emissions to 50% of that of 1980 for both countries in 2000.

Then examine the effects of this plan on the Norwegian environment in comparision with the official energy pathway scenario in which no SO2 reduction measures has been adopted by any country.

<u>ANALYSIS:</u>

STEP 1: <u>creating the scenario</u>

The scenario specified has been created in section 3.6 (example) and named as "ex3".

The RAINS version 4.0 enables the user to look at following 4 aspects of the environmental effect of the plan launched by Poland and Germany.

(a) the effects on total SO2 emissions from the two countries

(b) the effects on SO2 deposition within Norwegian territory

(c) the effects on Norwegian forest soil acidifications

(d) the effects on Norwegian lake acidifications

STEP 2: **Examining the effects on SO2 emissions** in the ENEM module address 1,2,4.

RAINS ENEM VERSION 4.0 (1. May 1988)
SULFUR EMISSIONS (kt SO2)

1960	1970	1975	1980	1985	1990	1995	2000
Official Energy Pathway +D							
2666	3289	2929	3199	2977	2813	2842	2871
compared to: ex3							
2666	3289	2929	3199	2977	2813	2842	1599
Official Energy Pathway +PL							
1718	3428	3870	4110	4136	3716	3877	4038
compared to: ex3							
1718	3428	3870	4110	4136	3716	3877	2055

STEP 3: **Examining the effects on SO2 depositions in Norway**

From the DEP module, the user may get the graphic displays of deposition isolines for both official pathway and ex3 scenario (for the sake of convenience, the user is advised to input the same threshold pH values). Any deviations of the output from that of the official energy pathway are caused by the Polish and Germany joint SO2 abatement action.

STEP 4: **Examining the effects on forest soil**

Run simulation for the scenario ex3 in the main menu option 6 - simulation of soil acidification

From the soil acidification module, the user may use the function of comparing the state of soil acidification (SSA) of two scenarios (address 3,1,2).

STEP 5: **Examining of the effects on lake water**

Run simulation for the scenario ex3 in the main menu option 7 - simulation of lake acidification.

From the lake module, the user may compare either pH or alk. of Norwegian lake waters of the two scenarios (address 4,1,1 - 4,2,3).

<u>Example 2:</u> According to the information from the RAINS model, design more concreit abatement strategies for Polish and German governments in order to restrict SO2 emissions to the same level as in example 1. And estimate the costs of this plan.

<u>Analysis:</u> Since the target absolute SO2 emission levels of scenario ex3 for the two countries have been calculated in step 2 example 1, using these figures, the user may find the cost optimal abatement strategies and the associated costs for each country by examining the national cost curves.

STEP 1: Calculating the target SO2 emission level (refer example 1, step 2)

F.R.Germany: 1599 kiloton surphur in 2000

Poland: 2055 kiloton surphur in 2000

STEP 2: Produceing the national cost curves for Poland and F.R.Germany (address 1,7).

STEP 3: Deciding on the abatement strategies

From the national cost curves, the user may not find the exact same emission level as the target level, but he/she may choose the strategies that generate closest level of SO2 emissions, then modify the strategies in step 4. In this case, strategies for Poland and Germany may be chosen as:

	F.R.Germany	***Poland***
strategy:	HC-PPn-FGD.	HC-CON-FGD
remained emission level:	1424 kt.	2011 kt.
cost:	2075 million DM.	1808 million DM

STEP 4: Creating a new scenario with the selected control strategies (address 1,5,2,3 and 1,5,2,5)

In this step, the user may use "try and error" method to find out a acceptable strategy for each country.

STEP 5: Calculating abatement costs by fuels, sectors, and countries in the cost submodule (address 1,4).

References

J. Alcamo, M. Amann, J.-P. Hettelingh, etc.

"Acidification in Europe: A simulation model for evaluating control strategies"
p232 - p244, AMBIO Vol.16, No.5. 1987.

Markus Amann & Gabor Kornai

"Cost functions for controlling SO2 emissions in Europe", Working paper, International Institute for Applied Systems Analysis, May 1987, WP-87-065, Laxenburg, Austria

M.J.Chadwick, J.G.Cooke, J.I.Kuylenstierna, etc.

"Acid deposition in Europe: Co-ordinated abatement strategies", an interim report, Beijer Institute, Stockholm, Sweden, 1987.

Text in RAINS's information system.

Appendices

Appendix 1. The output list

The output list

OUTPUTS	FORM	ADDRESS	DESCRIPTIONS
		range 1:	**energy, emission and cost**
		1,1	view energy data base
	T&G	1,1,1	fuels over time
	T&G	1,1,2	sectors over time
	T	1,1,3	per period: fuels over sectors
		1,2	view SO2 emissions calculation
	T&G	1,2,1	per country: fuels over time
	T&G	1,2,2	per country: sectors over time
	T	1,2,3	per country, per period: fuels over sectors
	T&G	1,2,4	compare emissions of two scenarios
	T	1,2,5	all countries, one period

	1,2,6	parameters
T	1,2,6,1	*sulfur content (per fuel and sector)*
T	1,2,6,2	*heat values of fuels*
T	1,2,6,3	*sulfur retention in ash*
T	1,2,6,4	*(implicit) emission factors*
	1,3	view NOx emission calculation
T&G	1,3,1	per country: fuels over time
T&G	1,3,2	per country: sectors over time
T	1,3,3	per country, per period: fuels over sectors
T&G	1,3,4	compare emissions of two scenarios
T	1,3,5	all countries, one time period
T	1,3,6	parameters (emission factors)
	1.4	view cost calculation
T&G	1,4,1	per country: fuels over time
T&G	1,4,2	per country: sectors over time
T	1,4,3	per country, per period: fuels over sectors

T&G	1,4,4	compare costs of two scenarios
T	1,4,5	abatement costs for all countries for one period
	1,4,6	parameters
T	1,4,6,1	*cost coefficients (per fuel and sector, per PJ)*
T	1,4,6,2	*cost coefficients (per fuel and sector, per Kt SO2)T*
T	1,4,6,4	*costs of fuel desulfurization*
	1,4,6,5	*control technologies: tech. specific parameters*
T	1,4,6,5,1	*combustion modification (new installations)*
T	1,4,6,5,2	*combustion modification (retrofit)*
T	1,4,6,5,3	*fuel gas desulfurization (new installations)*
T	1,4,6,5,4	*fuel gas desulfurization (retrofit)*
T	1,4,6,5,5	*regenerative process*
T	1,4,6,5,6	*general parameters for all technologies*
	1,4,6,6	*control technologies: country specific parameters*
T	1,4,6,6,1	*average boiler size - powerplants*
T	1,4,6,6,2	*average boiler size - industry*
T	1,4,6,6,3	*capacity utilization - powerplants*

T	1,4,6,6,4	*capacity utilization - industry*
T	1,4,6,6,5	*electricity price, labour costs, interest rate*
T	1,4,6,6,6	*sorbents costs*
T	1,4,6,6,7	*price for by-products and disposal costs*
T	1,4,6,7	*cost of process emissions removal*
T	1,4,6,8	*sulphur removal efficiencies (per fuel and sector)*
T&G	1,4,7	national cost curve
	1,5	execute control strategies
T	1,5,1	view energy use per fuel and sector
	1,5,2	country specific SO2 abatement
S	1,5,2,1	*fuel switching: powerplants*
S	1,5,2,2	*fuel switching: industry and domestic sectors*
S	1,5,2,3	*direct controls: powerplants*
S	1,5,2,4	*direct controls: industry*
S	1,5,2,5	*direct controls: conversion, domestic and transport*
S	1,5,2,6	*process emission control*
	1,5,3	global SO2 abatement options

S	1,5,3,1	*powerplants*
S	1,5,3,2	*industry*
S	1,5,3,3	*conversion, domestic and transport*
S	1,5,3,4	*process emission control*
	1,6	execute direct input of SO2 emissions
S	1,6,1	absolute numbers for each country
S	1,6,2	percents of 1980 for each country
S	1,6,3	percents of 1980 for all countries
	range 2:	**deposition of sulphur**
	2,1	deposition isoline due to a group of countries for a specific year
G	2,1,1	display of isolines for one scenario
G	2,1,2	comparision of isolines for two scenarios
G	2,1,3	display of isolines and their uncertainty range
G	2,2	comparision of 3 isoline values for 2 years
G	2,3	evolution of 1 isoline value for up to 6 years
	2,4	Time evolution of an area with a deposition level above certain given values

T	2,4,1	display percentage of area for one scenario
T	2,4,2	display percentage of area (compare two scenarios)
T	2,5	deposition at a specific location due to a group of countries
G	2,6	colored deposition pattern due to a group of countries for a specific year
	range 3:	**Soil acidification in Europe**
	3,1	state of soil acidification (SSA)
G	3,1,1	display state of soil acidification
G	3,1,2	compare SSA with another scenario
G	3,1,3	compare SSA with another year
G	3,2	areas with soils below a certain pH
T	3,3	time evolution of forest area below a certain pH value
	range 4:	**Lake acidification in Fennoscania**
	4,1	show annual mean-pH
T&G	4,1,1	look at pH of a simulated scenario
T&G	4,1,2	compare pH with another scenario pH
T&G	4,1,3	compare pH with another year pH

	4,2	show annual mean - alkalinity
T&G	4,2,1	look at alk. of a simulated scenario
T&G	4,2,2	compare alk. with another scenario alk.
T&G	4,2,3	compare alk. with another year alk.

Appendix 2. What's in the blackboxes?

For those who are interested in the contents in the blackboxes (modules), this appendix is designated to their satisfaction.

Box 1: SO2 emissions submodel

Sulfur emissions calculation:

Sectoral emissions per fuel:

$$S_{i,j,k}(t) = \sum_{l} E_{i,j,k,l}(t) \frac{sc_{i,j,k}}{hv_{i,j}} (1 - sr_{j,k})(1 - x_{i,k,l})$$

Total sulfur emissions per country:

$$S_i(t) = \sum_{j} \sum_{k} S_{i,j,k}(t) + S_i^P(t)$$

Symbols:

E	energy use
hv	heat value
sc	sulfur content
sr	fraction of emissions retained in ash
x	fraction of emissions removed by pollution control
S	sulfur emissions
S^P	sulfur emissions from industrial (non combustion) processes
i	country
j	fuel type
k	economic sector
l	abatement technology
t	time

Box 2: Cost analysis submodel

Direct abatement costs, C^d:

(for reasons of simplicity indices for countries (i), fuels (j) and sectors (k) are omitted where possible)

- pollution control measures without investments: c_l are taken from the literature
- abatement technologies, which require investments

$I_{an} = f(I, bs, v_j, lt, q)$

$OM_{fix} = f(I, bs, v_j, f_l)$

$OM_{var} = f(\alpha, c^e, \lambda^e, c^l, \lambda^l, c^s, \lambda^s, c^d, \lambda^d)$

$$c_l = \frac{I_{an} + OM_{fix}}{pf} + OM_{var} \frac{sc}{hv} (1 - sr)\ x$$

$$C^d = \sum_j \sum_k \sum_l E\ c_l$$

Fuel switching costs, C^f:

$$C^f = \sum_j \sum_k E\ cf - \sum_j \sum_k E^*\ cf$$

Control costs for process emissions, C^p:

$$C^p = S^{*p}\ xp\ cp$$

Total pollution control costs:

$$C_{i,t} = C^d + C^f + C^p$$

Symbols:

I_{an}	annualized investment costs
OM_{fix}	fixed operation and maintenance costs
OM_{var}	variable operation and maintenance costs
xp	efficiency of process emissions removal
cp	unit costs for process emissions removal
c_l	unit costs for direct abatement
cf	price differential for fuel substitution
E^*	energy use in original scenario
S^{*p}	unabated process emissions

Country specific data:

sc	sulfur content
hv	heat value
sr	sulfur retained in ash
bs	average boiler size
pf	capacity utilization
q	real interest rate
c^e, c^l, c^s, c^d	prices for electricity, labor, sorbents and waste disposal

Technology specific data:

I	investment function
v	relative flue gas volume
lt	life time of plant
x	sulfur removal efficiency
α	ratio sulfur/sorbents
f_l	maintenance costs
$\lambda^e, \lambda^l, \lambda^s, \lambda^d$	specific demand for energy, labor, sorbents and waste disposal

Box 3: Sulfur transport submodel

Symbols:

a	transfer coefficient: deposition per unit emissions	k_{w,c_1}	wet removal rate for SO_2
		k_{w,c_2}	wet removal rate for SO_4^{2-}
		n	grid element
b	background deposition	Q	emission flux
c_1	SO_2 air concentration	S_i	emissions from country i
c_2	SO_4^{2-} air concentration	t	time
$\frac{D}{dt}$	total time derivative	v_d	dry deposition velocity for SO_2
		w_d	dry deposition velocity for SO_4^{2-}
h	mixing height	α	local deposition coefficient
i	country	β	coefficient accounting for SO_4^{2-} emissions
k_t	transformation rate		

To compute deposition in RAINS:

$$d_n(t) = \sum_i S_i(t)\, a_{i,n} + b_n$$

The transfer coefficients, $a_{i,n}$ are derived from the EMEP model of sulfur transport in Europe with the basic equations:

$$\frac{Dc_1}{dt} = -\left[\frac{v_d}{h} + k_t + k_{w,c_1}\right] c_1 + (1-\alpha-\beta)\frac{Q}{h}$$

$$\frac{Dc_2}{dt} = -\left[\frac{w_d}{h} + k_{w,c_2}\, c_2\right] + k_t c_1 + \beta\frac{Q}{h}$$

Box 4: Soil acidification submodel

Weathering and cation exchange:

$$BC_{CE}(t) = BC_{CE}(t-1) - (ac(t) - wr)$$

Equilibrium concentrations:

$$c_H(t) = f(BC_{CE}(t),\ CEC_{tot})$$

$$c_{Al}(t) = K_{so} c_H^3(t)$$

Symbols:

BC_{CE}	prevailing cation-exchange capacity
CEC_{tot}	total cation-exchange capacity
ac	acid load rate to the soil
wr	silicate weathering rate
c_H	hydrogen ion concentration
c_{Al}	aluminum ion concentration
K_{so}	equilibrium constant for aluminum solubility
t	time

Box 5: Lake acidification submodel

Symbols:

Q_{tot}	total runoff
Q_a	quickflow (from A-layer)
Q_b	baseflow (from B-layer)
A_c	catchment area
A_l	lake area
κ_s	hydraulic conductivity
S	surface slope
Z_b	soil thickness in B-layer
Z_{tot}	total soil thickness
K_c	lumped equilibrium constant
t	time
w	catchment width
c_{HCO_3}	HCO_3^--concentration
c_H	H^+-concentration in A, B or lake (l)
wr	weathering rate
ac_f	acid load to forests
ac_o	acid load to open land
d_{tot}	total sulfur deposition
k_{SO_4}	in-lake SO_4 retention coeff.
$F_H^{(1)}$	flux of acidity from soil
$F_H^{(2)}$	flux of acidity directly on lake
$F_{HCO_3}^{(1)}$	flux of alkalinity from soil
$F_{HCO_3}^{(2)}$	flux of alkalinity from lake

Discharge from the lower soil layer (B):

$$Q_b = \kappa_s S W Z_b$$

Discharge from the upper soil layer (A):

$$Q_a = Q_{tot} - Q_b$$

Fluxes of acidity to lake:
(for calculation of concentrations see Box 5)

$$F_H^{(1)}(t) = Q_a \cdot c_{H,a}(t) + Q_b \cdot c_{H,b}(t)$$

$$F_H^{(2)}(t) = ac_o(t) \cdot A_l$$

Fluxes of alkalinity to lake:

$$F_{HCO_3}^{(1)}(t) = (wr \cdot Z_{tot} - ac_f(t))A_c$$

$$F_{HCO_3}^{(2)}(t) = \frac{k_{SO_4} d_{tot}(t)}{Q_{tot}/A_l + k_{SO_4}}$$

Equilibrium in lake mixing volume:

$$c_{H,l}(t) = \frac{K_c}{c_{HCO_3}(t)}$$

Appendix 3. Scenario information

1.Basic scenarios:

Scenario 1. **Official Energy Pathway**

This scenario describes the energy consumption projection up to the year 2000 as reported to IEA and ECE by individual governments (published in IEA Coal Report 1986 and ECE Energy Database1988). For a few countries that failed to submit forcasts for the year 2000, the missing data were compiled by IIASA using long-term trend extrapolation. As these energy consumption figures serve as basis for design of different emission reduction scenarios, the Official Energy Pathway assumes no pollution control and marks therefore the worst case of possible emission scenarios based on the official announced energy projections. Consequently the emission forecasts of this scenario does not reflect official projection of SO2 emission as most countries decided to reduce emissions by means of pollution control technologies.

Scenario 2. **Natural Gas Scenario**

This scenario explores the maximum potential of natural gas consumptions throughout Europe, which would arise in line with continuing technical progress in the fields of energy production, conversion and user technologies. This scenario was developed by IIASA's International Gas Study Group (see e.g. S. Messner, A.Golovine and M. Strubegger: Natural Gas in Europe; IIASAWP-86-39, 1986) and takes into account limitations of overall availability of resources, competition between different fuel types and conversion technologies as well as limited market penetration rates of new technologies.The data are at the moment only avaiable for countries in Central and Western Europe:

Austria, Belgium, Denmark, France, FRG,

Ireland, Luxembourg, Netherlands,

Scenario 3. **Maximum Feasible Reduction**

This scenario is based on energy assumptions of the Official Energy Pathway and is aimed at assessing the impacts of a radical decrease of SO2 emissions.It is assumed that all potential emission reduction acheivable with today's pollution control techniques are realized, but no measures are taken for energy conservation and fuel substitution. This strategy results in a decline of approximately 80% to 90% in SO2 emissions compared to that of the official energy pathway depending on the countries' energy consumption structure.

2.Derived Scenarios

RAINS provides the user with information about any scenarios which are derived from the three basic scenarios. The user may gain these information by pressing <8> from the main option menu of ENEM submodel.

The information provided by RAINS will be in such form:

Name: Scenario 30% reduction

derived from: Official Energy Pathway

The method of control: Global % data input.

Appendix 4. Abbreviations used by the RAINS model

1. Countries

* Albania (AL)	Austria (A)	Belgium (b)
* Bulgaria (BG)	Czechoslov. (CS)	Denmark (DK)
* Finland (SF)	France (F)	F.R.Germany (D)
* German, D.R. (DDR)	Greece (GR)	Hungary (H)
* Ireland (IRL)	Italy (I)	Luxemburg (L)
* Netherlands (NL)	Norway (N)	Poland (PL)
* Portugal (P)	Romania (R)	Spain (E)
* Sweden (S)	Switzerland (CH)	Turkey (TR)
* United Kingdom (UK)	USSR (SU)	Yogoslavia (YU)

2. Fuel types

Nr.	Fuel type (Abbr.)
1	Brown coal (BC)
2	Hard coal (HC)
3	Derived coal (DC)
4	Light oil (LF)
5	Medium destillate (MD)
6	Heavy oil (HF)

7	Gas	(GAS)
8	Other fuels	(OS)

3. The economic sectors

Nr.	**sector**	**(Abbr..)**
1	Conversion	(CON)
2	Power plants	(PP)
3	Domestic	(DOM)
4	Transport	(TRA)
5	Industry	(IND)

4. SO2 adatement techniques

* fuel substitution (FS)
* use of low sulphur fuels (LS)
* desulphurization
  - combustion modification (CM)
  - fuel gas desulphurizationn (FGD)
  - regenerative processes (RP)
* process emission control (process)