# An Operational Energy Modeling System

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**Abstract**

This report gives a detailed description of the different functions of the MARKAL Data Manager (MDM) as well as a user's manual for the online MARKAL-WEB site. Globally, the system is composed with a database for managing structural data, a set of routines implementing users oriented functionalities, and a set of AMPL-PERL scripts for I/O management and distance processing.

## 1 Introduction

A complete MARKAL-Lite[1] session is composed with: Data collection (database + data file description), Model running (AMPL script), and Results analysis (database and/or text file).

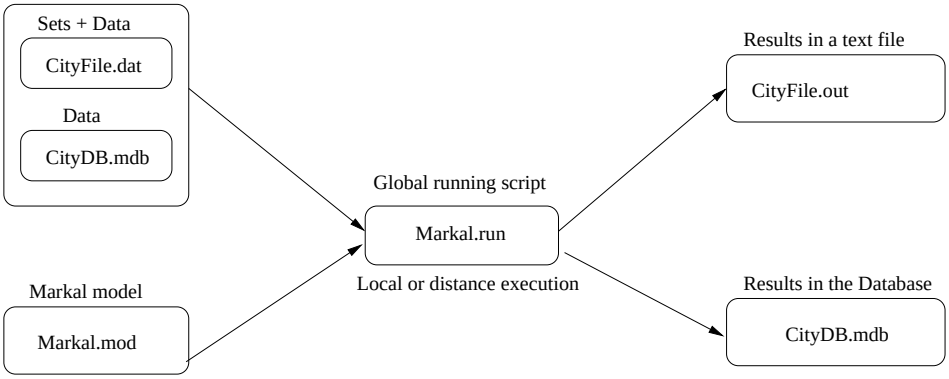


Figure 1: Markal Processing Structure

The model is a set of linear constraints, variable bounds, and an explicit formulation of the objective. Variables receive their values ethier from a database (.mdb) or from a text file (.dat). All variables are declared in the text file. Static variables are instanciated into the text file, while dynamic variables receives their values from the database. Static variables refer to data sets and some static parameters such as: time periods, daily divisions, seasonal divisions, period length, and others standard sets related to useful demands and technologies. Dynamic variables are used for technology parameters (life duration, energy consumption, costs, etc...), and also for outputs.

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For the first MARKAL step, which concerns data collection, the user has to prepare a set of data that will be passed as input for the model. The overall set of required data is grouped into four main categories:

- the useful demands
- the imported energy prices
- the list of all technologies with their technical and economic parameters
- the residual capacities

On top of that, the user will have to provide various bounds, in particular those concerning the pollutant emissions.

The present document gives a description of the different functions of the MARKAL Data Manager (MDM). It also gives a step-by-step instructions in the use of the tool. MARKAL DATA MANAGER provides assistance to the user for building and managing data sets and related parameters necessary for MARKAL running. The tool is available on the WEB at the following address :

http://ecolu-info.unige.ch/recherche/sutra/models/markal/workshop.htm

One needs **ACCESS 2000** running on a local machine in order to use the program. It is possible to use previous versions of ACCESS, provided one makes the required conversion.

The report is organized in two parts. The first part present MARKAL DATA MANAGER, which is a Database providing several functionalities to manage input and output data for MARKAL, and the second part describes the MARKAL-WEB system, which is a distance treatment web service for a complete online MARKAL session.

## 2 Starting MARKAL DATA MANAGER

The database program is started by opening the corresponding file **Markal2000_v4.mdb** (this program runs in the Microsoft Access © environment). The execution starts with the activation of the main frame (see Fig. 2)..

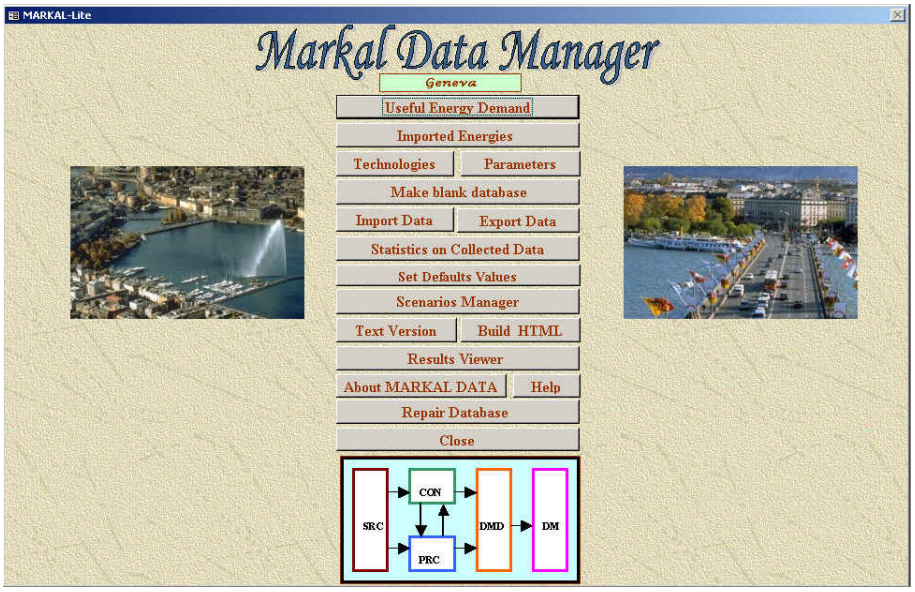



Figure 2: Main Frame of MARKAL DATA MANAGER.

On this main form, one has access to available features of the application.

| | | |
|---|---|---|
| **Useful Energy Demand** | : | Edition of useful demand items and values. |
| **Imported Energies** | : | Edition of different kind of energy and their prices. |
| **Technologies** | : | Edition of technologies. |
| **Parameters** | : | Edition of parameters values for technologies. |
| **Make blank database** | : | Create an empty database. |
| **Import Data** | : | Import data from another database. |
| **Export Data** | : | Creation of a database with only data. |
| **Statistic on collected data** | : | Analyze data and report problems. |
| **Set Default Values** | : | Edition of default values for parameters. |
| **Scenario Manager** | : | Management of scenarios. |
| **Text Version** | : | Generation of a data file for AMPL purpose . |
| **Build HTML** | : | Generate of html reports of data. |
| **Result Viewer** | : | Visualization of MARKAL results. |
| **About MARKAL DATA** | : | Application name, version, and Authors. |
| **Help** | : | Help on the use of the application. |
| **Repair Database** | : | Automatic repairing of operating system problems. |
| **Close** | : | Close the application. |

# 3 Useful Energy Demands

In this step, the user can edit the list of useful energy demands. For each useful demand, a reference key code is given along with the description and the sector. When selecting **Useful Energy Demands**, a window appears as in Fig. 3.

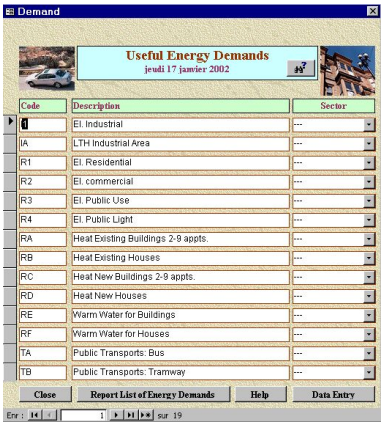



Figure 3: Useful Energy Demands.

Items on this list correspond to the energy demands for Geneva and most probably need to be modified in several places in order to correspond to the needs of the city. By selecting a particular useful energy demand, for example, **Electricity Industrial**, and clicking on **Data Entry** one may obtain the following template..

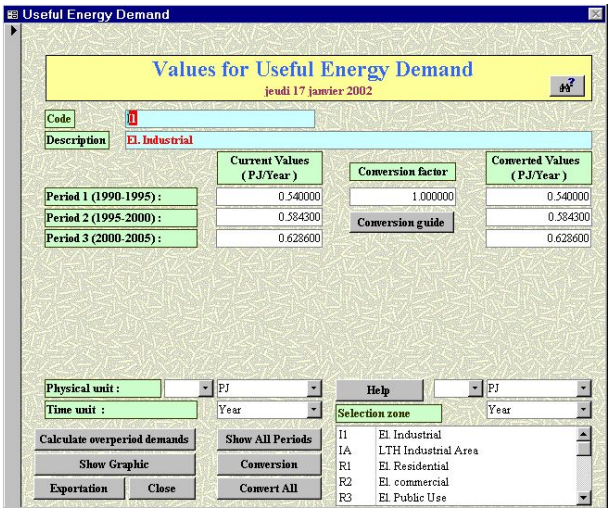



Figure 4: Data tool for Useful Energy Demands.

A number of features are available on this page.

• Data is entered in boxes labeled physical units and time units. The units that are typically used (for example PJ/year) are those used in the Geneva example, however units may be changed

according to the data set in question. The complete MARKAL scenario will be displayed by clicking the **Show All Periods** option. This option will show the complete list of data for the given description. Usually, the user gets the values for the first three periods (called *observed periods*), and the values for future period should be estimated. For this purpose, there is a calculation system which performs the required estimation according to the model chosen by the user.

• **Calculate Overperiod Demands** is a routine for future period demands (also exists for energy prices). When the user clicks on the **Calculate Overperiod Demands**, she gets a calculation window on top of which the useful demand description and the last value observed are displayed. A forecasting calculation is then performed by selecting one of these three options :

• *A constant growth rate* : This corresponds to an exponential evolution with a constant rate (i.e. $v_{t+1} = v_0(1+\alpha)^t$). The starting value for extrapolation is the last observed value (we assume that it is the value of the third period, but it can be changed), and the constant $\alpha$ has to be provided. The button **Get tendancy** calculates an estimation of the growth rate using the past periods values, and then proposes this growth to the user.

• *Linear piecewise interpolation* : This corresponds to a linear behavior with different slopes. The user first provides the number of pieces (intervals), and provides the values at the end of each interval. The resulting calculation is a linear interpolation of the points provided.

• *Exponential piecewise interpolation* : Same as previous, but an exponential interpolation is done instead of the linear one.


Figure 5: The calculation of futur periods demands using a constant growth rate model..

The result of a linear piecewise interpolation model is shown in Fig. 6.

The corresponding graphic is shown if Fig. 7. This graphic is obtained by cliking on the button **show graphic** and it is automatically updated whenever their is a change on data source.

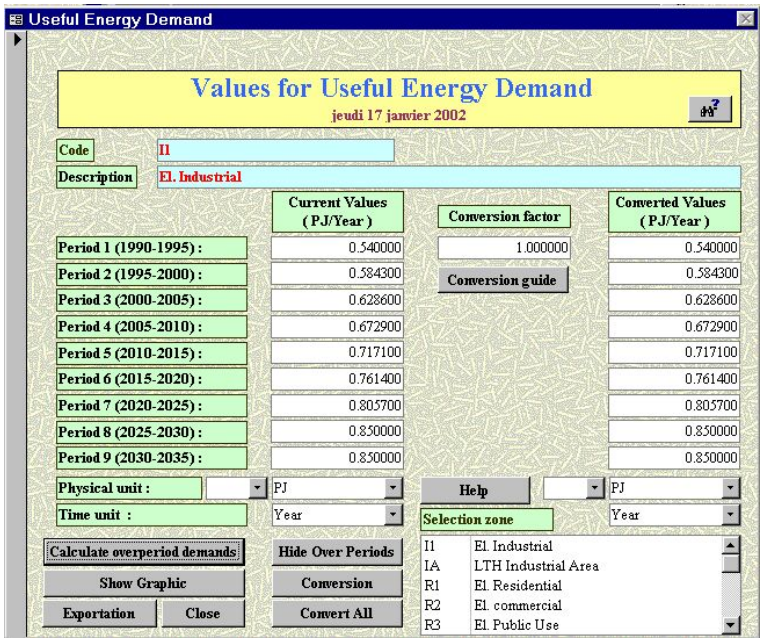



Figure 6: The future periods are shown in data page of Useful Energy Demands.

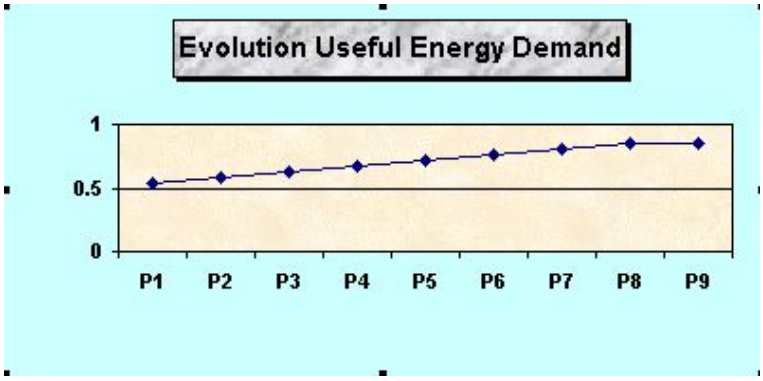
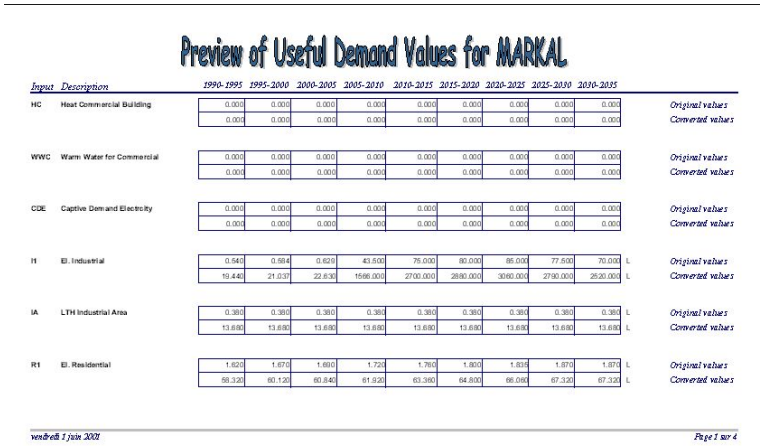



Figure 7: The graphic showing the evolution of the **Electricity Industrial** demand over the nine MARKAL periods. This data was calculated using a linear piecewise interpolation.

• Finally, a preview of collected data may be seen as a static report. It contains the list of all useful demands items and associated data. The style of the report is predefined and cannot be changed at the user level. A small part of a data preview is seen in Fig. 8.



Preview of Useful Demand Values for MARKAL

| Input | Description | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | 2020-2025 | 2025-2030 | 2030-2035 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HC | Heat Commercial Building | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Original values |
| | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Converted values |
| WWC | Warm Water for Commercial | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Original values |
| | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Converted values |
| CDE | Captive Demand Electricity | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Original values |
| | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | Converted values |
| I1 | El. Industrial | 0.540 | 0.584 | 0.629 | 43.500 | 75.000 | 80.000 | 85.000 | 77.500 | 70.000 | L | Original values |
| | | 19.440 | 21.037 | 22.630 | 1566.000 | 2700.000 | 2880.000 | 3060.000 | 2790.000 | 2520.000 | L | Converted values |
| IA | LTH Industrial Area | 0.380 | 0.380 | 0.380 | 0.380 | 0.380 | 0.380 | 0.380 | 0.380 | 0.380 | L | Original values |
| | | 13.680 | 13.680 | 13.680 | 13.680 | 13.680 | 13.680 | 13.680 | 13.680 | 13.680 | L | Converted values |
| R1 | El. Residential | 1.620 | 1.670 | 1.660 | 1.720 | 1.760 | 1.800 | 1.830 | 1.870 | 1.870 | L | Original values |
| | | 58.320 | 60.120 | 60.840 | 61.920 | 63.360 | 64.800 | 66.060 | 67.320 | 67.320 | L | Converted values |

vendredi 1 juin 2001 Page 1 sur 4

Figure 8: One of the pages in the Useful Demand Values preview listing.

• The data may be exported for producing a *.dat file running in the **AMPL** environment. Options are available for exportation in simple text, EXCEL format, or HTML. Exportation of data is done via the **Exportation** option in the menu.

# 4 Energy Import Prices

The list of energy sources will appear on the screen upon clicking **Energy Import Prices**. One will see a list as in Fig. 9. This page contains the relevant pricing information for the first two time periods, 1990-1995 and 1995-2000. The past evolution of energy import prices is obtained from local sources. Energy data for MARKAL-Lite (Geneva) was determined using informations obtained from the International Commission for Energy (*l'Agence International de l'Energie*)[6]. In the Geneva example, all energy prices were modeled to remain stable after 2015. One should insert the import prices for each relevant energy source. In order to add an energy source, one goes to the bottom of the page and edits the code and the description for each energy item (see figure Fig. 9).

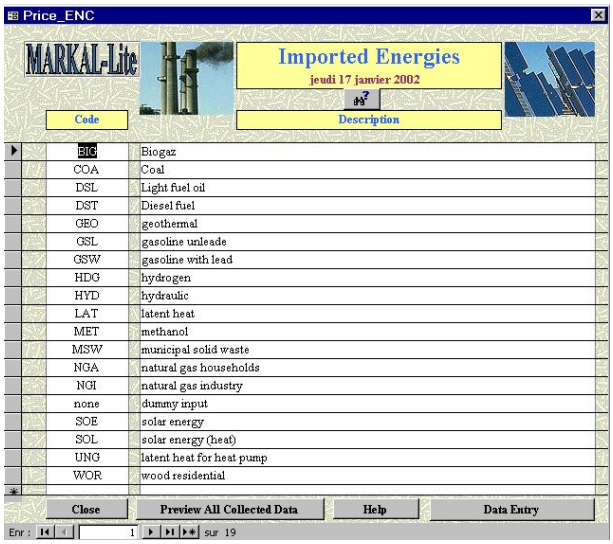
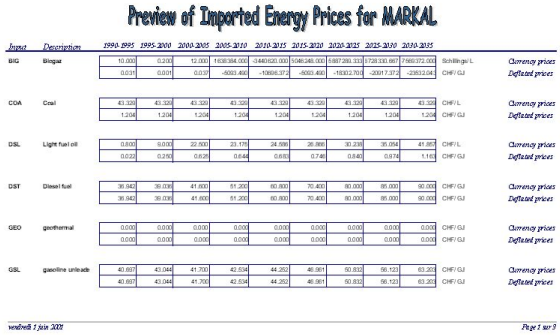



Figure 9: Imported Energies : Code and description.

An example of a **Preview of Imported Energy** as a report is given in figure Fig. 10. This report can be directly printed or save into a desired file format.



Preview of Imported Energy Prices for MARKAL

| Input | Description | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | 2020-2025 | 2025-2030 | 2030-2035 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BIG | Biogaz | 10.000 | 0.200 | 12.000 | -1638394.000 | -3446620.000 | 5046248.000 | 6887289.333 | 5728330.667 | 7569372.000 | Schillinge/ L | Currency prices |
| | | 0.015 | 0.001 | 0.019 | -6003.466 | -10866.372 | -6003.466 | -19012.700 | -20017.372 | -23013.04 | CHF/ GJ | Deflated prices |
| COA | Coal | 43.320 | 43.320 | 43.320 | 43.320 | 43.320 | 43.320 | 43.320 | 43.320 | 43.320 | CHF/ L | Currency prices |
| | | 1.204 | 1.204 | 1.204 | 1.204 | 1.204 | 1.204 | 1.204 | 1.204 | 1.204 | CHF/ GJ | Deflated prices |
| DSL | Light fuel oil | 0.600 | 0.000 | 22.500 | 23.175 | 24.506 | 26.866 | 30.239 | 36.094 | 41.865 | CHF/ L | Currency prices |
| | | 0.022 | 0.210 | 0.628 | 0.644 | 0.681 | 0.746 | 0.840 | 0.974 | 1.163 | CHF/ GJ | Deflated prices |
| DST | Diesel fuel | 36.942 | 39.036 | 41.600 | 51.200 | 60.800 | 70.400 | 80.000 | 85.000 | 90.000 | CHF/ GJ | Currency prices |
| | | 36.942 | 39.036 | 41.600 | 51.200 | 60.800 | 70.400 | 80.000 | 85.000 | 90.000 | CHF/ GJ | Deflated prices |
| GEO | geothermal | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | CHF/ GJ | Currency prices |
| | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | CHF/ GJ | Deflated prices |
| GSL | gasoline unleade | 40.697 | 43.044 | 41.700 | 42.534 | 44.252 | 46.861 | 50.832 | 56.123 | 63.202 | CHF/ GJ | Currency prices |
| | | 40.697 | 43.044 | 41.700 | 42.534 | 44.252 | 46.861 | 50.832 | 56.123 | 63.202 | CHF/ GJ | Deflated prices |

vendredi 1 juin 2001 Page 1 sur 3

Figure 10: An example of the preview of Imported Energy prices for MARKAL.

Like in the case of *useful demands*, there are several features for editing energy items (code, description) and their prices (value, currency).. One may select a specific energy source and

update it price.. For example, if *diesel fuel* is selected, a black triangle should be positioned in front of the code and a description for diesel fuel will be indicated. One next clicks on **Data Entry**, at the bottom of the screen (Fig. 9). When the correct energy source is selected, one is then ready to open the page (See Fig. 11).

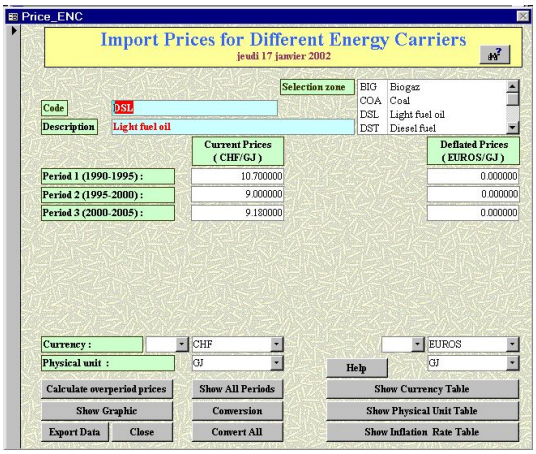



Figure 11: Data tool for Import Prices for different energy carriers. This example is for **Light Fuel Oil**.

The price units are in the currency of the country in question (or the economic space), and the energy units are typically in Giga-Joules, GJ ($10^9$ Joules), or Peta-Joules, PJ ($10^15$ Joules). Other energy units are also available, but the user should take care of the unit he uses because there will be a certain scailing on data.

• The **Show All Periods/Hide Over periods** allows one to see the nine MARKAL periods (or hide the futur periods values), see Fig. 12.

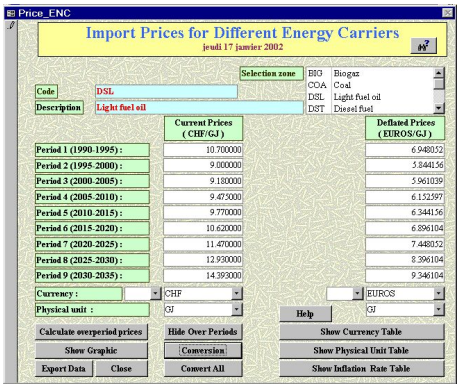



Figure 12: Data tool for Import Prices for different energy carriers showing the future periods.

• The **Conversion** option updates the Deflated Price column. The deflated price is calculated by dividing the current import price by the inflation rate. See Fig. 13.

• The **Convert All** option allows one to see a pop-up window stating that this operation will

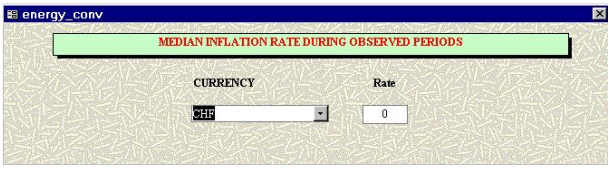
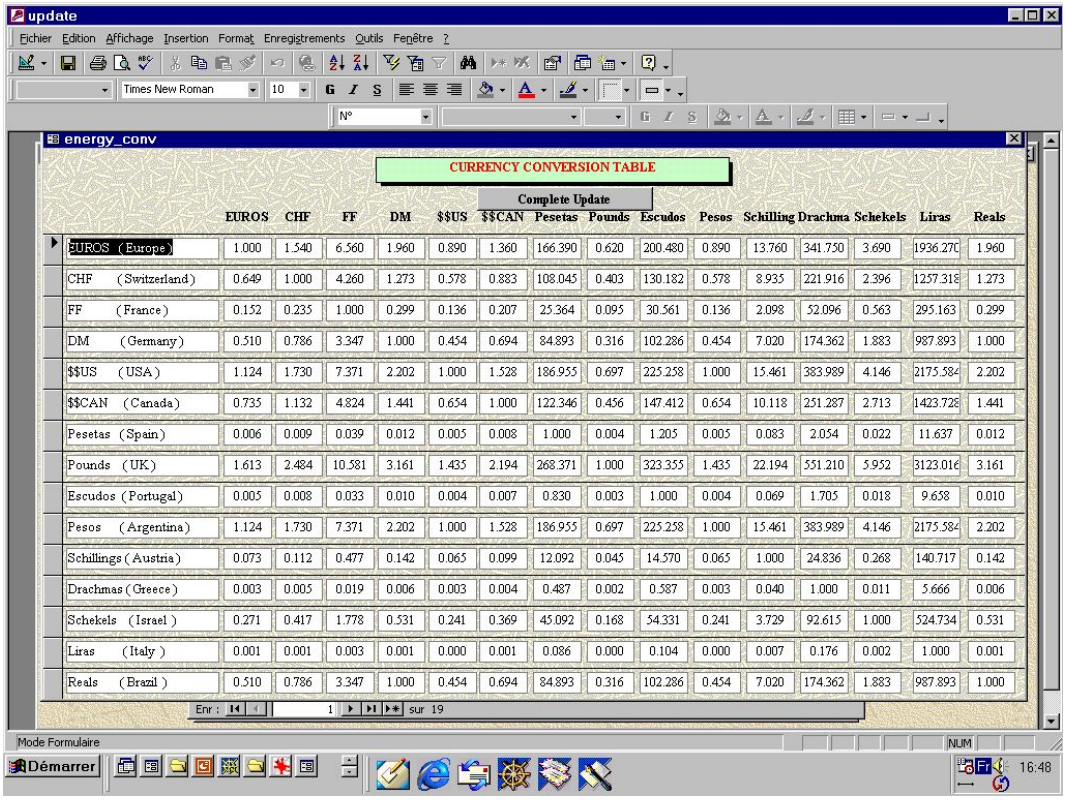



Figure 13: The calculation option for the median inflation rate of Import Energy Prices.

convert all deflated prices of all energies and periods into the current reference unit.

• The **Show Currency Table** option will pull up the currency conversion table. A complete list of former European and American currencies is shown. The update of one of the values will automatically affect the entire table using the appropriate linear scaling. A **Complete Update** option at the top of this page allows a full table update. The currency denominations are shown in Fig. 14.




| | EUROS | CHF | FF | DM | $$US | $$CAN | Pesetas | Pounds | Escudos | Pesos | Schilling | Drachma | Schekels | Liras | Reals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EUROS (Europe) | 1.000 | 1.540 | 6.560 | 1.960 | 0.890 | 1.360 | 166.390 | 0.620 | 200.480 | 0.890 | 13.760 | 341.750 | 3.690 | 1936.270 | 1.960 |
| CHF (Switzerland) | 0.649 | 1.000 | 4.260 | 1.273 | 0.578 | 0.883 | 108.045 | 0.403 | 130.182 | 0.578 | 8.935 | 221.916 | 2.396 | 1257.318 | 1.273 |
| FF (France) | 0.152 | 0.235 | 1.000 | 0.299 | 0.136 | 0.207 | 25.364 | 0.095 | 30.561 | 0.136 | 2.098 | 52.096 | 0.563 | 295.163 | 0.299 |
| DM (Germany) | 0.510 | 0.786 | 3.347 | 1.000 | 0.454 | 0.694 | 84.893 | 0.316 | 102.286 | 0.454 | 7.020 | 174.362 | 1.883 | 987.893 | 1.000 |
| $$US (USA) | 1.124 | 1.730 | 7.371 | 2.202 | 1.000 | 1.528 | 186.955 | 0.697 | 225.258 | 1.000 | 15.461 | 383.989 | 4.146 | 2175.584 | 2.202 |
| $$CAN (Canada) | 0.735 | 1.132 | 4.824 | 1.441 | 0.654 | 1.000 | 122.346 | 0.456 | 147.412 | 0.654 | 10.118 | 251.287 | 2.713 | 1423.728 | 1.441 |
| Pesetas (Spain) | 0.006 | 0.009 | 0.039 | 0.012 | 0.005 | 0.008 | 1.000 | 0.004 | 1.205 | 0.005 | 0.083 | 2.054 | 0.022 | 11.637 | 0.012 |
| Pounds (UK) | 1.613 | 2.484 | 10.581 | 3.161 | 1.435 | 2.194 | 268.371 | 1.000 | 323.355 | 1.435 | 22.194 | 551.210 | 5.952 | 3123.016 | 3.161 |
| Escudos (Portugal) | 0.005 | 0.008 | 0.033 | 0.010 | 0.004 | 0.007 | 0.830 | 0.003 | 1.000 | 0.004 | 0.069 | 1.705 | 0.018 | 9.658 | 0.010 |
| Pesos (Argentina) | 1.124 | 1.730 | 7.371 | 2.202 | 1.000 | 1.528 | 186.955 | 0.697 | 225.258 | 1.000 | 15.461 | 383.989 | 4.146 | 2175.584 | 2.202 |
| Schillings (Austria) | 0.073 | 0.112 | 0.477 | 0.142 | 0.065 | 0.099 | 12.092 | 0.045 | 14.570 | 0.065 | 1.000 | 24.836 | 0.268 | 140.717 | 0.142 |
| Drachmas (Greece) | 0.003 | 0.005 | 0.019 | 0.006 | 0.003 | 0.004 | 0.487 | 0.002 | 0.587 | 0.003 | 0.040 | 1.000 | 0.011 | 5.666 | 0.006 |
| Schekels (Israel) | 0.271 | 0.417 | 1.778 | 0.531 | 0.241 | 0.369 | 45.092 | 0.168 | 54.331 | 0.241 | 3.729 | 92.615 | 1.000 | 524.734 | 0.531 |
| Liras (Italy) | 0.001 | 0.001 | 0.003 | 0.001 | 0.000 | 0.001 | 0.086 | 0.000 | 0.104 | 0.000 | 0.007 | 0.176 | 0.002 | 1.000 | 0.001 |
| Reals (Brazil) | 0.510 | 0.786 | 3.347 | 1.000 | 0.454 | 0.694 | 84.893 | 0.316 | 102.286 | 0.454 | 7.020 | 174.362 | 1.883 | 987.893 | 1.000 |

Figure 14: The currency conversion table.

• The **Show Physical Unit** is an option that invokes a pop-up window where the user may insert various useful physical conversions. This table is used for each energy source in the database. See Fig. 15

• Finally, an option exists to **Export Data**. Data may be exported (either with the current price or deflated price). The exportation menu appears as in Fig. 16.

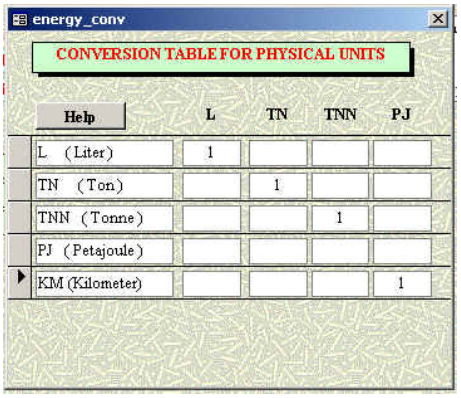



Figure 15: The physical unit conversion table.

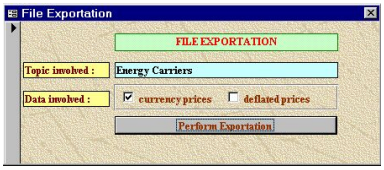



Figure 16: File Exportation

# 5 Technology Sets

This section presents the management of the different technology sets used in the MARKAL framework. The sets are the *centralized* and *decentralized* conversion technologies, and the demand devices sets, i.e, *electrical, heating and transport devices*. The technology template appears in figure Fig. 17. The user has to click on the appropriate button to edit the list of technologies for the selected set.


Figure 17: The Technology main page.

• The set of *centralized* and *decentralized* technologies may be edited in order to correspond to an individual city's needs. The decentralized technology page is shown in figure Fig. 18.


Figure 18: An example of the decentralized conversion technologies

• The complete list of all Technologies is shown in Fig. 19. The list can be filtered by sector, and for each technology the user can request for all associated values.

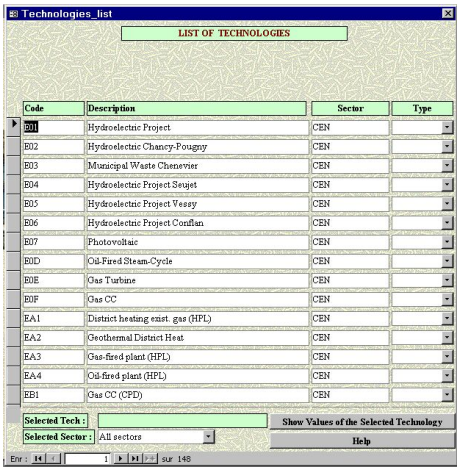



Figure 19: The list of technologies.

• The list of technologies should be edited according to the reference sector and useful demands. Recall that we associate the DMD technologies with the demands sector to which they belongs (see section 6 for more details). The figure Fig. 20 shows the list of transportation devices. Items along with their description may be added or deleted.

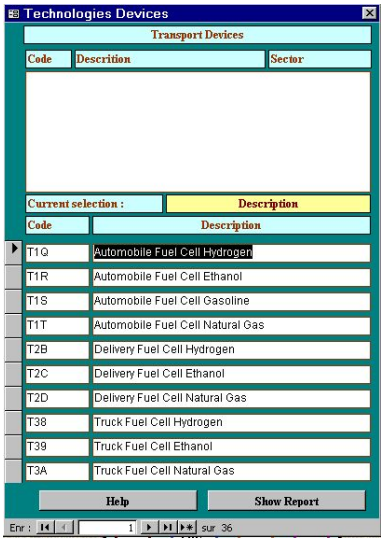



Figure 20: The technology list for transport devices.

• A report of the technology set may be obtained using the **Show Report** option. A full list of technologies is available and appears as in Fig. 21. The different demand sectors (including their description and their code) are found by selecting **List of Technologies**:

**Transport Technologies Set**

| Code | Demand | Code | Devices |
|---|---|---|---|
| T1 | | | |
| | | T1R | : Automobile Fuel Cell Ethanol |
| | | T1S | : Automobile Fuel Cell Gasoline |
| | | T1T | : Automobile Fuel Cell Natural Ga |
| T2 | | | |
| | | T2C | : Delivery Fuel Cell Ethanol |
| | | T2D | : Delivery Fuel Cell Natural Gas |
| T3 | | | |
| | | T39 | : Truck Fuel Cell Ethanol |
| | | T3A | : Truck Fuel Cell Natural Gas |
| T4 | | | |
| | | T4G | : Bus Fuel Cell Natural Gas |
| | | T4H | : Bus Fuel Cell Ethanol |
| TA | Public Transports: Bus | | |
| | | TA1 | : Trolleybus |
| | | TAH | : Bus Hydrogen |
| | | TAM1 | : Bus methanol 90% |
| | | TAM2 | : Bus methanol 100% |
| TB | Public Transports: Tramw | | |
| TC | Public Transports: Train | | |
| TD | Public Transports Misc. | | |
| TE | Automobile | | |
| | | TE2 | : Automobile, catal |
| | | TE3 | : Automobile gasoline w. lead |
| | | TE4 | : Automobile Diesel French |
| | | TE5 | : Automobile catal French |

Figure 21: The preview of the Transport Technologies Set.

# 6 Association between devices and useful demands

Each useful demand sector is associated with a set of devices that contribute to satisfy the energy service requirements. In our system, useful demands items and devices can be entered independently. Thus, we need to indicate the link between each useful demand item and its associated technologies. These informations will be used by the dictionary generator to produce the file input sets for the model. See Fig. 22.

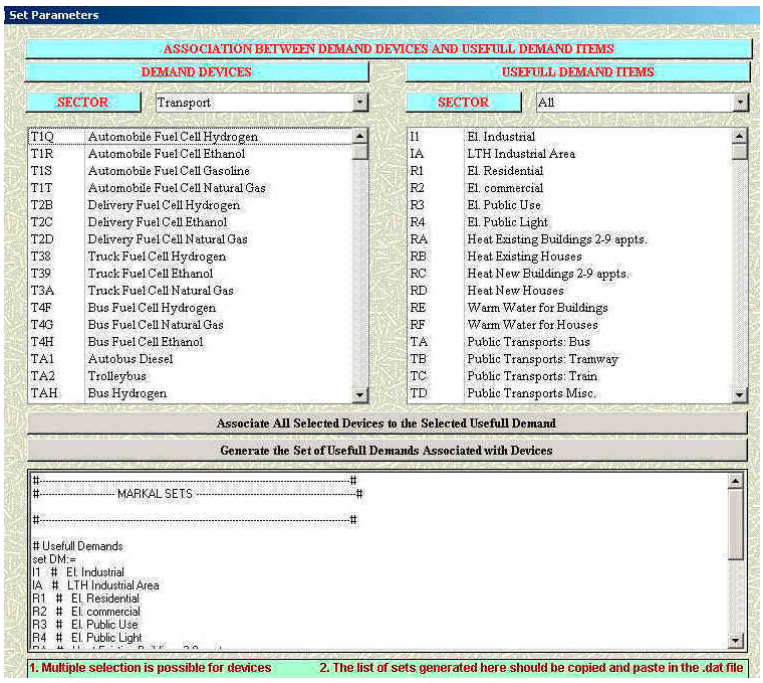



Figure 22: Association between useful demands and devices.

• From this panel, one selects a demand item (on the left hand side) and one (or several) devices (on the right hand side). The association is made by clicking on the button **Associate All Selected Devices to the selected Useful Demand**. This operation should be done until all the usefull demand sectors are covered. **This operation is crucial and should be done carefully in order to avoid missings or wrong semantic**.

• Clicking on the button **Generate the Set of Usefull Demands Associated with Devices** will produce a text file written in a standard AMPL format, with an explicit description of each set that will be considered by the model. This operation can also help for data checking. The resulting text file (usually associated with the extension **.dat**) will be used as a complement of the database. In fact, the database only provides data without any indication about how they should be considered in the construction of sets (for AMPL model). Thus, an associated descriptive file (in the AMPL syntax) is required to specify how each sets are built within data.

# 7 Technology Parameters

Once all sets of technologies have been edited, the user has to provide the value of each parameter for all the technologies involved. From the windows of figure Fig. 17, the user should click on the button **Parameters for Devices** to open the parameters management frame of figure Fig. 23 .

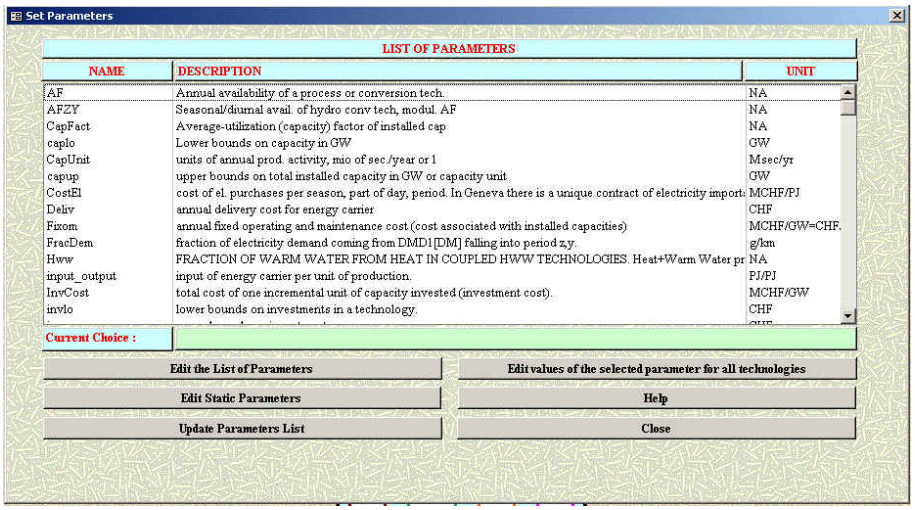



Figure 23: The parameter input table.

In the list of figure Fig. 23 , all parameters are displayed (code, description, and units). The user can edit the items of this list (particularly units) by clicking on the button **Edit the List of Parameters**. This gives acces tothe following windows (figure Fig. 24 ).

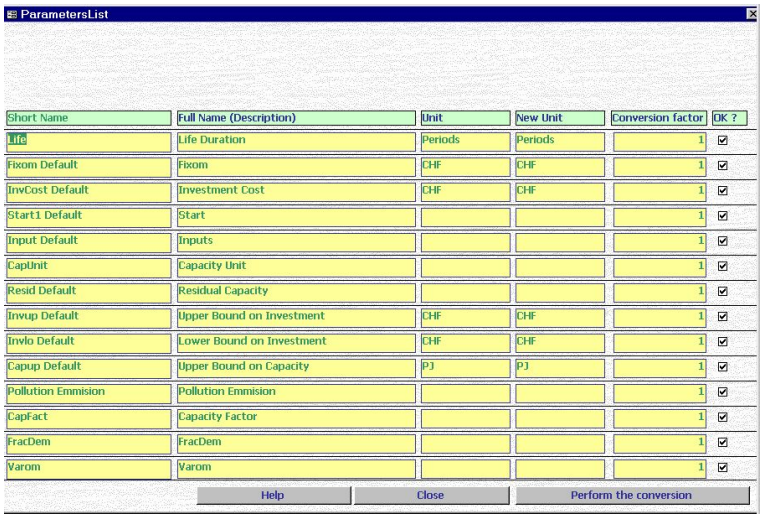



Figure 24: Edition of parameters list.

For each parameter, we have to provide a value for all technologies. There are two ways to enter values for parameters.

• The first way is to select a parameter, and then enter the values for all involved technologies. The template for entering parameters values depends on the dimension of the relevant parameter that can be

- one-dimensional, for parameters like *life*. See Fig. 25.
- two-dimensional, for parameters involved with periods consideration (*investment cost*,...).

See Fig. 26.

- three-dimensional, for parameters involved with periods consideration and another factor like *season* or *the moment of the day*. See Fig. 27.

• The second way is to select a given technology and then edit a table which contains the list of parameter values associated with this technology (see Fig. 34).

life [number of time periods of availability (life duration).]

| Code | number of time periods of availability (life duration). | Life |
|---|---|---|
| E01 | Hydroelectric Project | 10 |
| E02 | Hydroelectric Chancy-Pougny | 10 |
| E03 | Municipal Waste Chenevier | 10 |
| E04 | Hydroelectric Project Seujet | 10 |
| E05 | Hydroelectric Project Vessy | 10 |
| E06 | Hydroelectric Project Conflan | 10 |
| E07 | Photovoltaic | 5 |
| E0D | Oil-Fired Steam-Cycle | 6 |
| E0E | Gas Turbine | 4 |
| E0F | Gas CC | 5 |
| E6A | Industrial Cogen. Gas Turbine (5 MW) | 5 |
| E6B | Industrial Cogen. STEAM Turbine (5 MW) | 5 |
| E6C | Industrial Combined Cycle CC (5 MW) | 5 |
| E90 | Cogeneration INDustry (Motor) | 3 |

FILTER ON SECTOR :

Show Report | Help

Enr : 1 sur 155

Figure 25: One dimensional parameter window.

For a given parameter, the user can produce a report. The example of the parameter *life* is given in figure Fig. 28 .

The button **Update Parameters List** executes a routine for restablishing the data integrity of the database. In fact, when one removes (resp. adds) a technology, the corresponding parameters should be deleted (resp. added). The present routine attempts to perform this operation from the list of available technonolgies.

Fixom [annual fixed operating and maintenance cost (cost associated with installed capacities)]

annual fixed operating and maintenance cost (cost associated with installed capacities)

| Code | Description | Period1 | Period2 | Period3 | Period4 | Period5 | Period6 | Period7 |
|---|---|---|---|---|---|---|---|---|
| E01 | Hydroelectric Project | 0 | 0 | 0 | 0 | 0 | 0 | |
| E02 | Hydroelectric Chancy-Pougny | 0 | 0.666 | 0 | 0 | 0 | 0 | |
| E03 | Municipal Waste Chenevier | 0 | 0 | 0 | 0 | 0 | 0 | |
| E04 | Hydroelectric Project Seujet | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86. |
| E05 | Hydroelectric Project Vessy | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86. |
| E06 | Hydroelectric Project Conflan | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86.58 | 86. |
| E07 | Photovoltaic | 296.37 | 296.37 | 296.37 | 296.37 | 296.37 | 296.37 | 296. |
| E0D | Oil-Fired Steam-Cycle | 61.4718 | 61.4718 | 61.4718 | 61.4718 | 61.4718 | 61.4718 | 61.47 |
| E0E | Gas Turbine | 31.1688 | 32.61402 | 34.05258 | 35.4978 | 36.94302 | 38.38824 | 39.82 |
| E0F | Gas CC | 31.1688 | 32.61402 | 34.05258 | 35.4978 | 36.94302 | 38.38824 | 39.82 |
| E6A | Industrial Cogen. Gas Turbine (5 M | 51.948 | 51.948 | 51.948 | 51.948 | 51.948 | 51.948 | 51.9 |
| E6B | Industrial Cogen. STEAM Turbine | 138.528 | 138.528 | 138.528 | 138.528 | 138.528 | 138.528 | 138.5 |
| E6C | Industrial Combined Cycle CC (5 M | 45.0216 | 45.0216 | 45.0216 | 45.0216 | 45.0216 | 45.0216 | 45.02 |
| E90 | Cogeneration INDustry (Motor) | 69.264 | 69.264 | 69.264 | 69.264 | 60.606 | 60.606 | 60.6 |
| E9G | Cogeneration COMM (Motor) | 43.29 | 43.29 | 43.29 | 43.29 | 43.29 | 42.64065 | 41.99 |
| E9R | Cogeneration RESID (Motor) | 61.4718 | 61.4718 | 61.4718 | 61.4718 | 49.3506 | 48.4848 | 47.6 |
| EA1 | District heating exist. gas (HPL) | 0 | 0 | 0 | 0 | 0 | 0 | |

Help

Enr : 1 sur 155

Figure 26: Two dimensional parameter window.

input_output [input of energy carrier per unit of production.]

Select an Area for Filtering : Transport

| Code | Description |
|---|---|
| T1Q | Automobile Fuel Cell Hydrogen |
| T1R | Automobile Fuel Cell Ethanol |
| T1S | Automobile Fuel Cell Gasoline |
| T1T | Automobile Fuel Cell Natural Gas |
| T2B | Delivery Fuel Cell Hydrogen |
| T2C | Delivery Fuel Cell Ethanol |
| T2D | Delivery Fuel Cell Natural Gas |

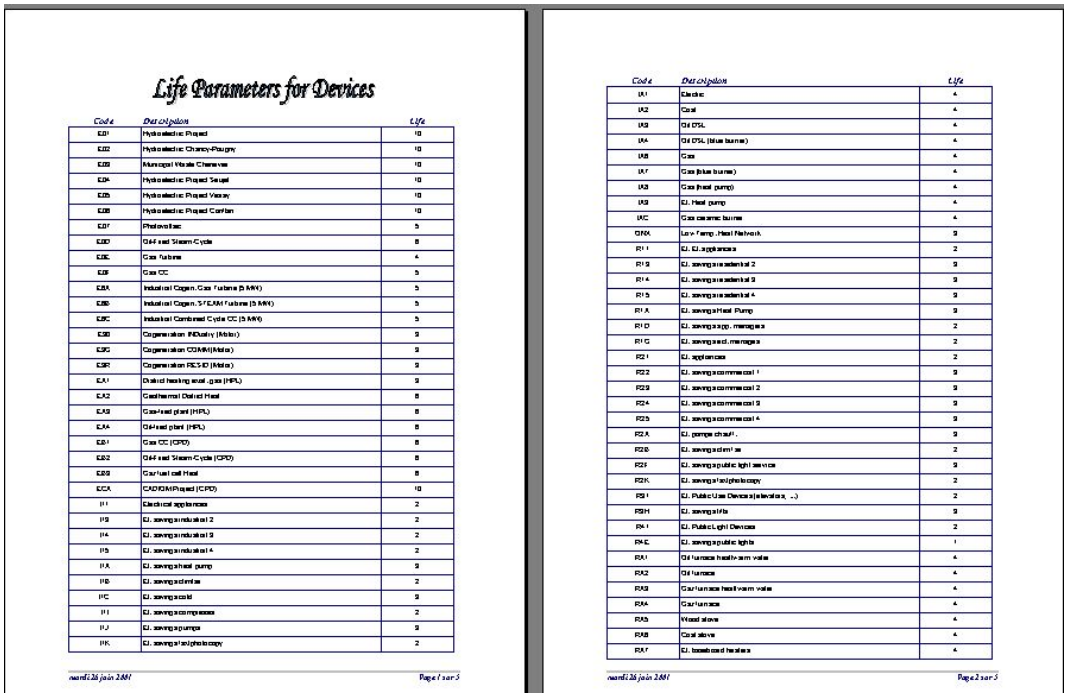
| List of Energy Carriers | |
|---|---|
| BIG | Biogaz |
| COA | Coal |
| DSL | Light fuel oil |
| DST | Diesel fuel |
| ETH | Ethanol EURO-125 |
| GEO | geothermal |
| GSL | gasoline unleade |

| Code | Input | Description | Period 1 | Period 2 | Period 3 | Period 4 | Period 5 | Period 6 | Period 7 | Period 8 | Period 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEN | NGI | Automobile natural gaz | 0.001786 | 0.001786 | 0.001786 | 0.001786 | 0.001786 | 0.001786 | 0.001786 | 0.001786 | 0.00178 |
| T1T | NGI | Automobile Fuel Cell Natural Gas | 0.000416 | 0.000416 | 0.000416 | 0.000416 | 0.000416 | 0.000416 | 0.000416 | 0.000416 | 0.00041 |
| T2D | NGI | Delivery Fuel Cell Natural Gas | 0.000828 | 0.000828 | 0.000828 | 0.000828 | 0.000828 | 0.000828 | 0.000828 | 0.000828 | 0.00082 |
| T3A | NGI | Truck Fuel Cell Natural Gas | 0.003025 | 0.003025 | 0.003025 | 0.003025 | 0.003025 | 0.003025 | 0.003025 | 0.003025 | 0.00302 |
| T4G | NGI | Bus Fuel Cell Natural Gas | 0.003983 | 0.003983 | 0.003983 | 0.003983 | 0.003983 | 0.003983 | 0.003983 | 0.003983 | 0.00398 |
| TA2 | ELC | Trolleybus | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.00013 |
| TB1 | ELC | Tramway | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.000137 | 0.00013 |
| TC1 | ELC | Train | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.00437 |
| TD1 | ELC | Miscellanous | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.004379 | 0.00437 |

Close helpB Show Report

Enr : 1 sur 44 (Filtré)

Figure 27: Three dimensional parameter window.



## Life Parameters for Devices

| Code | Description | Life |
|---|---|---|
| E01 | Hydroelectric Project | 10 |
| E02 | Hydroelectric Chaney-Paugny | 10 |
| E03 | Municipal Waste Chenevee | 10 |
| E04 | Hydroelectric Project Seuzal | 10 |
| E05 | Hydroelectric Project Vessy | 10 |
| E06 | Hydroelectric Project Conflan | 10 |
| E07 | Photovoltaic | 5 |
| E0D | Oil-fired Steam Cycle | 8 |
| E0E | Gas turbine | 4 |
| E0F | Gas CC | 5 |
| E0A | Industrial Cogen. Gas Turbine (5 MW) | 5 |
| E0B | Industrial Cogen. STEAM turbine (5 MW) | 5 |
| E0C | Industrial Combined Cycle CC (5 MW) | 5 |
| E0D | Cogeneration INDustry (Motor) | 9 |
| E0G | Cogeneration COMM (Motor) | 9 |
| E0H | Cogeneration RESID (Motor) | 9 |
| EA1 | District heating wood, gas (HPL) | 9 |
| EA2 | Geothermal District Heat | 8 |
| EA3 | Gas-fired plant (HPL) | 8 |
| EA4 | Oil-fired plant (HPL) | 8 |
| E0I | Gas CC (CPD) | 8 |
| E0J | Oil-fired Steam Cycle (CPD) | 8 |
| E0G | Gas fuel cell Heat | 8 |
| ECA | CAD/CAM Project (CPD) | 10 |
| I11 | Electrical appliances | 2 |
| I13 | El. saving in industrial 2 | 2 |
| I14 | El. saving in industrial 3 | 2 |
| I15 | El. saving in industrial 4 | 2 |
| I1A | El. saving in heat pump | 9 |
| I1B | El. saving in climate | 2 |
| I1C | El. saving in cold | 9 |
| I1I | El. saving in compressors | 2 |
| I1J | El. saving in pumps | 9 |
| I1K | El. saving in photocopy | 2 |

mardi 26 juin 2001 Page 1 sur 5

| Code | Description | Life |
|---|---|---|
| IA1 | Electric | 4 |
| IA2 | Coal | 4 |
| IA3 | Oil DSL | 4 |
| IA4 | Oil DSL (blue burner) | 4 |
| IA5 | Gas | 4 |
| IA7 | Gas (blue burner) | 4 |
| IA8 | Gas (heat pump) | 4 |
| IA9 | El. Heat pump | 4 |
| IAC | Gas ceramic burner | 4 |
| CINA | Low Temp. Heat Network | 9 |
| R11 | El. El. appliances | 2 |
| R13 | El. saving in residential 2 | 9 |
| R14 | El. saving in residential 3 | 9 |
| R15 | El. saving in residential 4 | 9 |
| R1A | El. saving in Heat Pump | 9 |
| R1D | El. saving in pp. menagers | 2 |
| R1G | El. saving in ed. menagers | 2 |
| R21 | El. appliances | 2 |
| R22 | El. saving in commercial 1 | 9 |
| R23 | El. saving in commercial 2 | 9 |
| R24 | El. saving in commercial 3 | 9 |
| R25 | El. saving in commercial 4 | 9 |
| R2A | El. pompe chaud. | 9 |
| R2B | El. saving in climate | 2 |
| R2I | El. saving in public light service | 9 |
| R2K | El. saving in photocopy | 2 |
| R3I | El. Public Use Devices (television, ...) | 2 |
| R3H | El. saving in Info | 9 |
| R41 | El. Public Light Devices | 2 |
| R4E | El. saving in public lights | 1 |
| RA1 | Oil furnace heat+warm water | 4 |
| RA2 | Oil furnace | 4 |
| RA3 | Gas furnace heat+warm water | 4 |
| RA4 | Gas furnace | 4 |
| RA5 | Wood stove | 4 |
| RA6 | Coal stove | 4 |
| RA7 | El. baseboard heaters | 4 |

mardi 26 juin 2001 Page 2 sur 5

Figure 28: The listing of the life parameter for different technology devices.

# 8 Setting default values

Default values for the technology parameters are set in this window. A default value is attached to each parameter. Note that this default value is used only to fill missing inputs.

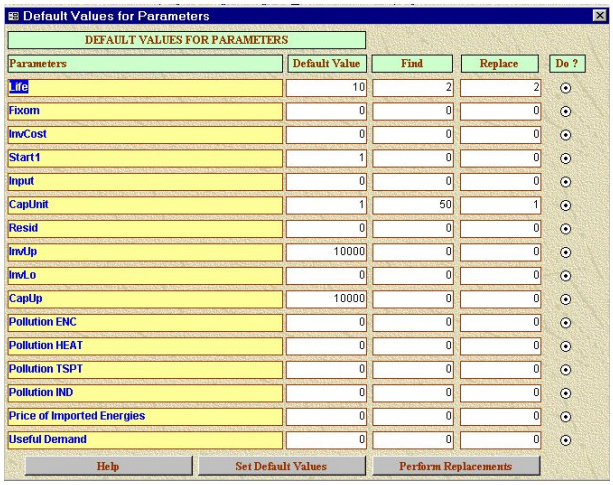



Figure 29: Adjusting the default settings for the different parameters.

# 9 Starting a new Database

A new database may be created with MARKAL-Lite DMSS. A menu allows for the selection of different sectors to be included or not included with the new database. See Fig. 30.

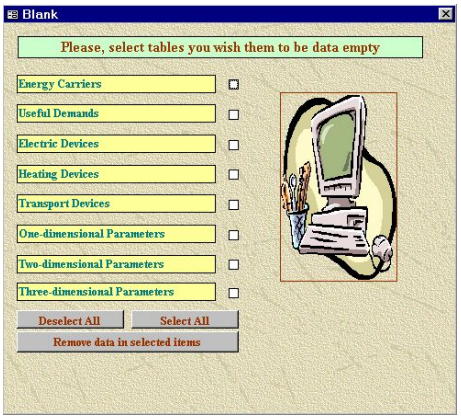



Figure 30: The online option for making a new database.

# 10 Loading and Saving the database

Data may be loaded (imported from another database) or saved (exported into another database) using the options **Load Database** and **Save Database**. The IMPORT database window is shown in Fig. 31.

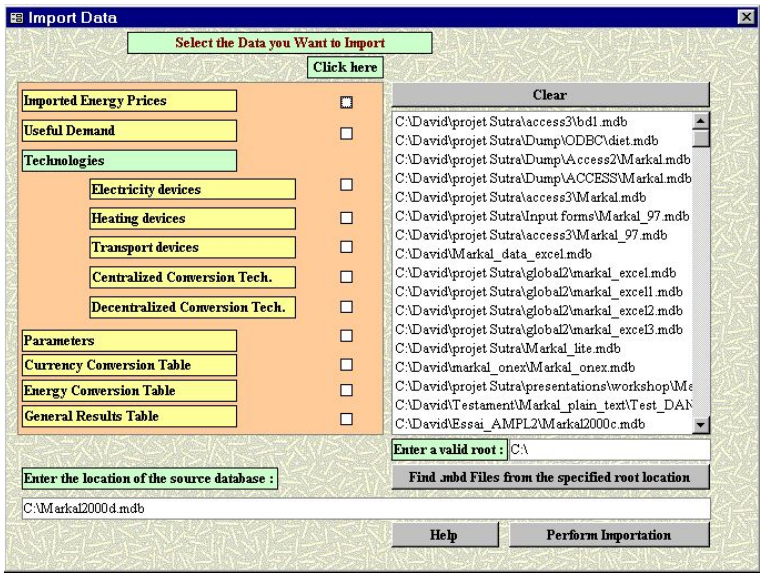



Figure 31: **Importing a database** page. One may select an available database from the list on the right, or enter the full pathname on the text area for file name. One also has the option of including only parts of a database by selecting the appropriate options on the left.

By clicking on the white window, one may select the different parts of the database to be loaded. The name and path of the database is to be typed into the selection of the pop up window. This is usefull when a new version of the application is made available, or when a user wants to integrate some data coming from another city case.

The database may be saved by selecting the **save** option. This action produces a data bank (only data) for running the model or other transfer purposes. Since the size of the data is very small compared to the size of the whole application, using the exportation issue helps for faster transfers (See Fig. 32).

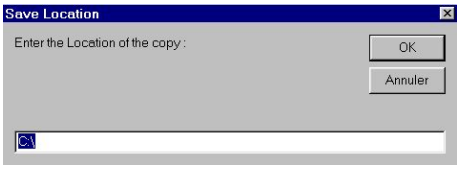



Figure 32: Saving the database to a specific location.

# 11 Statistics on collected data

A statistical analysis may be performed on the data before running MARKAL. An example of a fresh report is shown in 33.

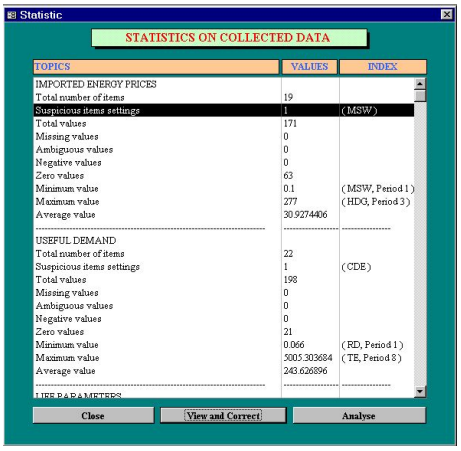



Figure 33: The statistics collected on the data.

A suspicious data alert is integrated in the MARKAL DATA MANAGER. If suspicious data appears, the user may examine the data more closely by clicking and viewing the erroneous data. By selecting a particular statistic that is listed with suspicious data one may adjust values that are labeled as missing or have unusual fluctuations.

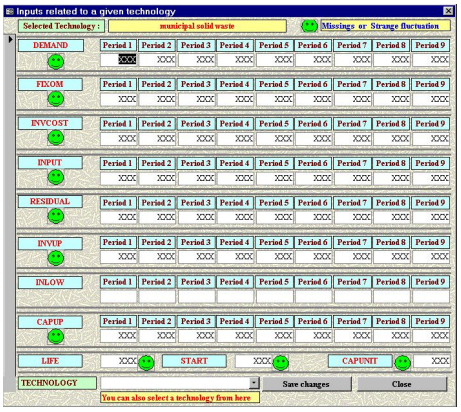



Figure 34: Viewing and correcting data.

Each selected technology will appear along with the values for each period. The user may modify the data (if necessary) and then save the changes.

## 12 Scenario Manager

A scenario manager is used to generate a list of relationships between urban/technical factors and useful demands. To build a scenario, we just need to instantiate the values associated to the previous factors, and then the system will automatically produce the corresponding values for useful demands and related. The generator template appears as in Fig. 35.

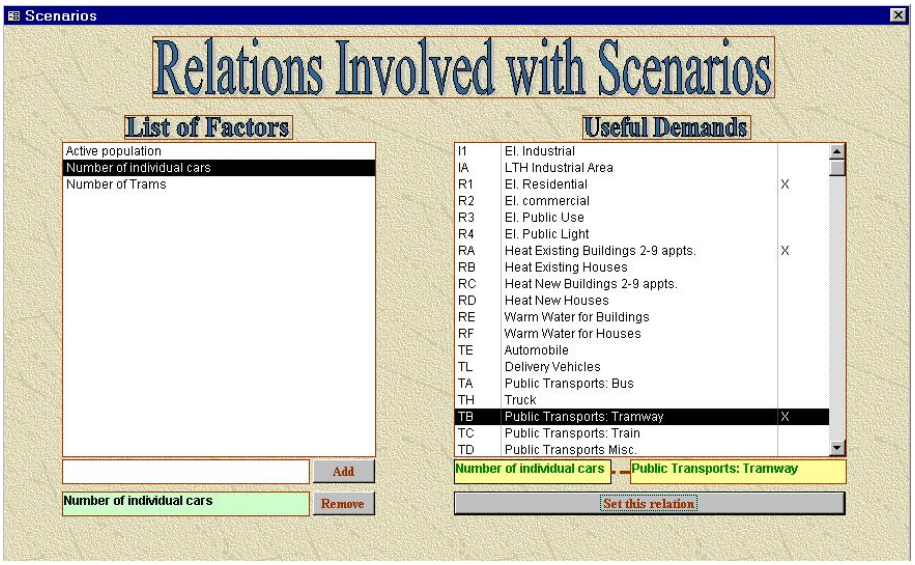



Figure 35: The scenario manager with the adjustable list of factors and the list of useful demands.

On the left hand side of the windows (figure Fig. , 35), the user provides a list of urban, economic, and atmospheric factors that have an influence on useful demands values. For instance, if the price of public transport services decreases, then one should expect an increasing demand on public transport. The way factors are linked to the corresponding demands should be specified, also the way the factor itself should be quantified. At this step, we are only insterested by the relationship between factors and useful demands, and the corresponding association modelling.

To produce a scenario, the user performs some changes to the previous factors and requests for the transformations on the data according to the association relationship and quantitative model. This operation produces a new database from a source one.

Automatic changes can also be done on paramaters values by appying a scalling on the data of a source database. For instance, one can chose to increase the life duration of transport technologies by a factor of 2. This is another way to produce scenarios.

Whatever the case, the results you will obtain will be a conjunction of all implications of the previous data changes. Note that this part of the system is not completely operational, some analysis and implementations remain to be done..

# 13 Specifications for Building Sets

In order to run the MARKAL code written in AMPL, one needs to provide some specifications about the sets that are to be used in the model. As some of these specifications are based on items available in the database, it follows that the task of building the sets may be taken up by the database application. Figure Fig. 36 displays the working windows associated to this operation.

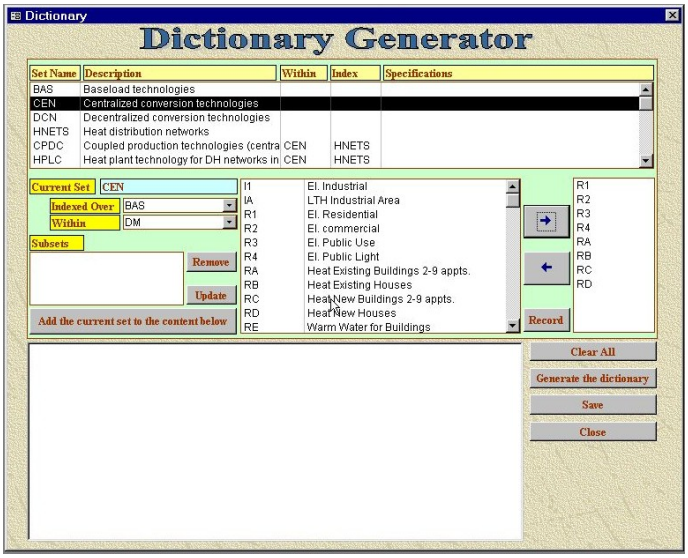



Figure 36: Building sets with *Markal Data Manager*

A working session can be described as follows. The user first provides the list of sets and some basic informations (name, description). This operation is done by opening the corresponding box for edition (double-click on the box). Next, since the list of principal sets is available, each of them is to be specified. For this purpose, the user first selects the set on the list and next performs one of the following operations :

- Enter the elements of the set. This is done in the editor mode as previously described. These elements are listed with a blank space as separation, and without any additive symbol (e.g: A1 A2 B1 B2 ).
- Build the list of elements by first selecting the data table where elements are found (this refers to the AMPL clause **within**). When this is done, all the values of the selected data table are listed, and the user simply chooses the elements to be recorded.
- Build the list of the subsets of the current set. This is done by selecting the indexing set, and then editing the list that is automatically generated. Next, the resulting list can be transferred in the principal list of sets.

When a set is ready, the corresponding specifications can be written in the edit box for the set specification file. At the end, the user can save the contents in the edit box into a file (*.dat). This file will be used for MARKAL processing.

# 14 Building and visualizing the results

When the MARKAL processing is achieved, an important remaining issue is to observe and analyze the results obtained. There are two principal ways of displaying the results, it can be numericaly, graphicaly, or both. The total set of results may be large and one must select only some contents for viewing. This content is a projection of the global set of results data restricted to a given context (sector, period, pollutant,...). A tool is provided that allows the user to easily display results and perfoms filtering as desired, see Fig. 37.

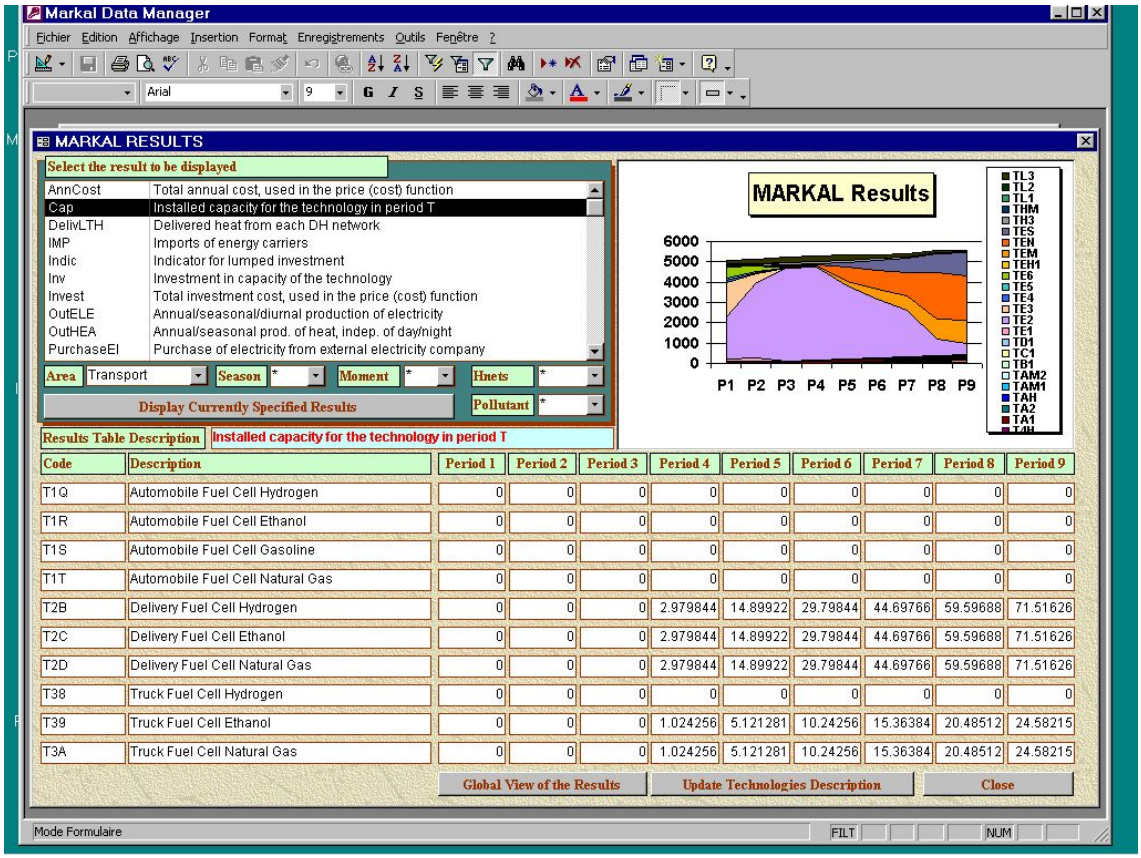



Figure 37: Building and visualizing results with *Markal Data Manager*

After running the model, we have provided a post-process routine in AMPL that aggregates all the result variables into one variable that is written in the target database. At this step, the results are available in the database and the user can open the viewer form and analyze the data both numerically and graphically.

The option **Update Technologies Description** associated the descrition of each technology in the result table. This makes the result more easy to appreciate.

# 15 Create an html output

An interesting feature provided by MARKAL DATA MANAGER is the possibility to produce an html version of the database. The user is asked for some metadata like the name of the city, the name/contact of the head of the project, the name/contact of the members of the team. After that, the system produces a coherent system of html files for a user friendly consultation of the data.
An example of html output is shown in figure Fig. 39 for the Geneva case.

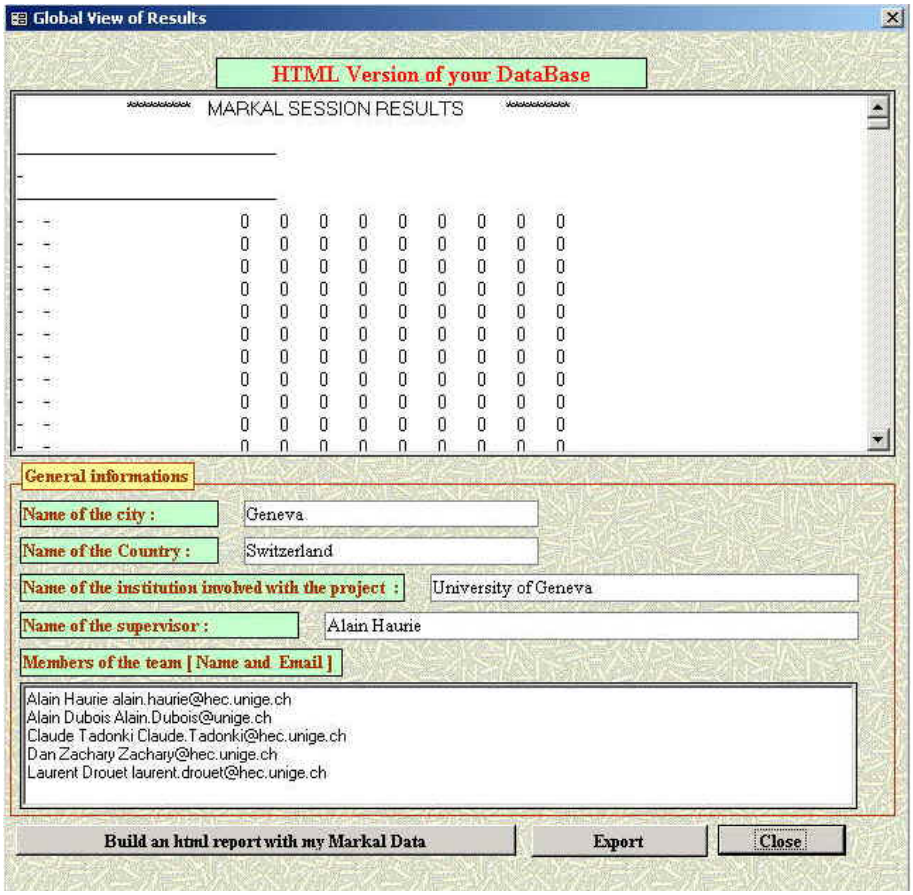



Figure 38: Building an html output *Markal Data Manager*

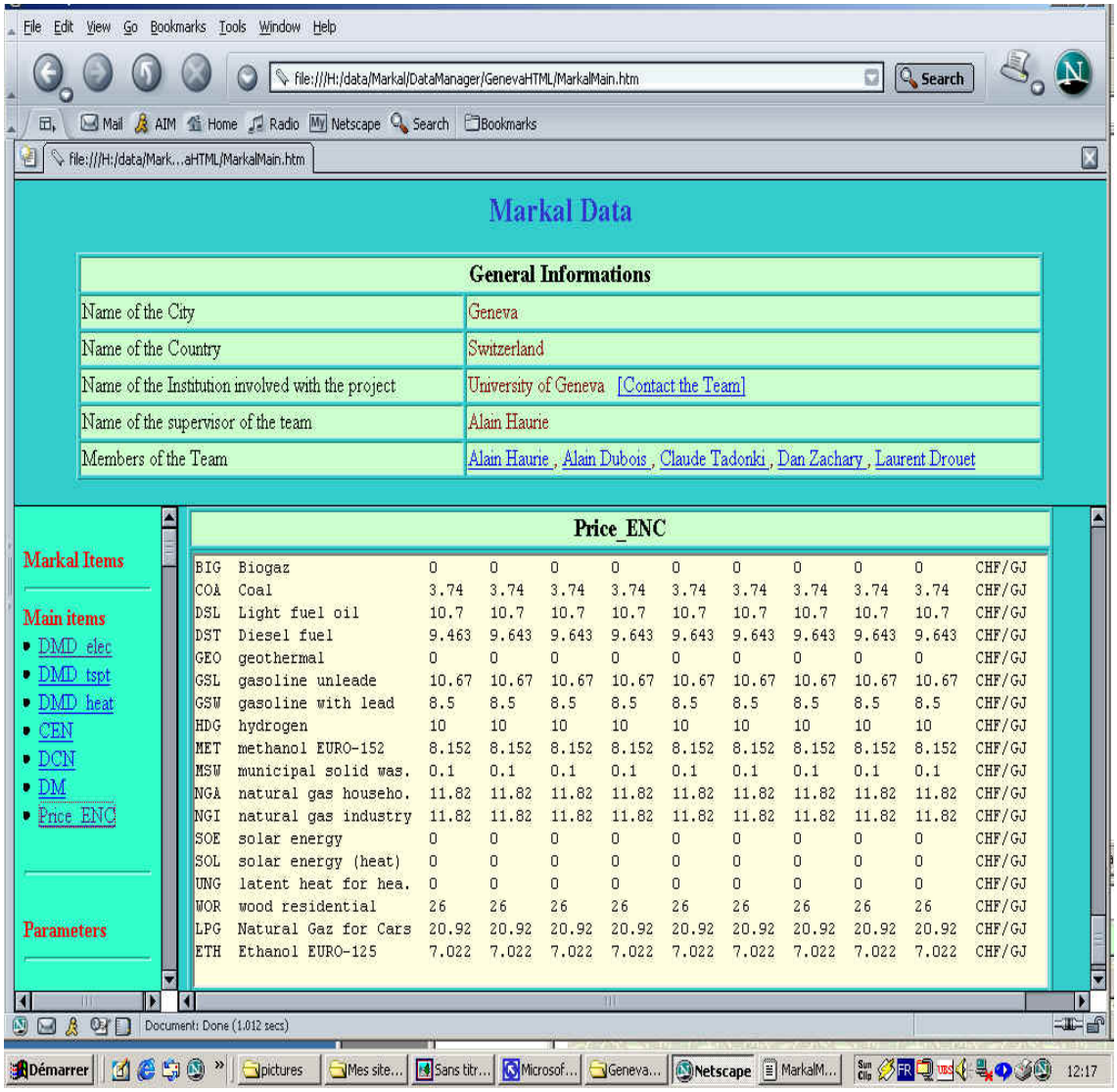



Figure 39: A sample html output using *Markal Data Manager*

# 16 Distance Processing

## 16.1 Presentation

**Description**
MARKAL WEB is an Internet application that permits the remote operation of the MARKAL energy model via the WEB. The selected optimization problem is submitted to the server, where the **AMPL** interface and the **XPRESS** solver are installed.

**Requirements** :

- A browser
- The Markal input files composed by the Access database, a MARKAL model file *.mod in **AMPL** , a data file *.dat in **AMPL**, a control file to read the data from the Access database through ODBC, an output control file to specify the desired results.
- An FTP client (optional)

**Operation** :
The following steps are required ::

- Transfer the input files on the server either by FTP or through the upload page.
- Select the files for the optimization run of Markal.
- Submit the optimization problem to the server.
- Download the result written in the Access database

There are two ways to run the MARKAL model. The first is to select all the required files one by one (a model file *.mod, a data file *.dat, an Access database *.mdb, an ”output file *.out” that specifies the results that will be written either by ODBC in the Access database or written in a simple ASCII text file usually named sol_auto.txt). The second way is to specify a single ”run file *.run” that contains all the batch commands to be sent to **AMPL**[3] to run the optimization.
This is an example of an **AMPL** run file :

```
# University of Geneva, Alain Dubois, 22/01/2002
# File : markal_web.txt
#  sample batch  file for Markal Web run

reset; reset options;  # reset the AMPL options

# below is the chosen model file, full physical path is required
model e:\user\markal_web\geneva\markal_v5_mod.txt;

#  below is the chosen data file with the definitions of the sets
data e:\user\markal_web\geneva\markal_v5_dat.txt;

# below is an automatic generated "ODBC  read file"  from the chosen Access
# database
include e:\user\markal_web\geneva\markal_v5_odbc_tmp.txt;

# below are the option for the solver and the display
option display_width 300;
option solver xpress; # definition for the XPRESS solver
option presolve 0;
option show_stats 1;
```

```
option display_lcol 0;

solve;

# below is the output file that defines the results to be written in the
# Access database
 include e:\user\markal_web\geneva\markal_v5_out.txt;

quit; # close AMPL
```

Location :
The starting page of MARKAL WEB is located at

`http://ecolunt1.unige.ch/markal_web/`

The FTP server for MARKAL WEB is :

`ftp://ecolunt1.unige.ch/markal_web/`

Each city case has its own directory to store the data and to operate the MARKAL WEB application:

| City | URL | physical path |
|---|---|---|
| Buenos Aires | http://ecolunt1.unige.ch/markal_web/buenos_aires | e:/user/markal_web/buenos_aires/ |
| Gdansk | http://ecolunt1.unige.ch/markal_web/gdansk | e:/user/markal_web/gdansk/ |
| Geneva | http://ecolunt1.unige.ch/markal_web/geneva | e:/user/markal_web/geneva/ |
| Genoa | http://ecolunt1.unige.ch/markal_web/genoa | e:/user/markal_web/genoa/ |
| Lisbon | http://ecolunt1.unige.ch/markal_web/lisbon | e:/user/markal_web/lisbon/ |
| Tel-Aviv | http://ecolunt1.unige.ch/markal_web/tel_aviv | e:/user/markal_web/tel_aviv/ |
| Thessaloniki | http://ecolunt1.unige.ch/markal_web/thessaloniki | e:/user/markal_web/thessaloniki/ |

Input files :

**Model file** :

This is an ASCII text file written with the **AMPL** syntax which describes the optimization problem to be solved. It can be the same file as used in a local run of MARKAL on a computer equipped with **AMPL** and a solver (eg. **XPRESS**)

**Data file** :

This is an ASCII text file in the **AMPL** syntax that describes the ”sets” to be used.

**Access database** :

It contains the data for all the parameters coming out of the MARKAL database application.

**Output file** :

This file describes the commands to write the results of the MARKAL run either in a ASCII text file or in the **AMPL** syntax to a ODBC table used in the Access database.

Result file:
If the problem is feasible and the solver has found a solution, the results are usually written in a table in the same Access database where the input tables are found. The MARKAL Access application can be used to analyze and visualize the results of the MARKAL run.


Figure 40: Screen shot of the upload page.

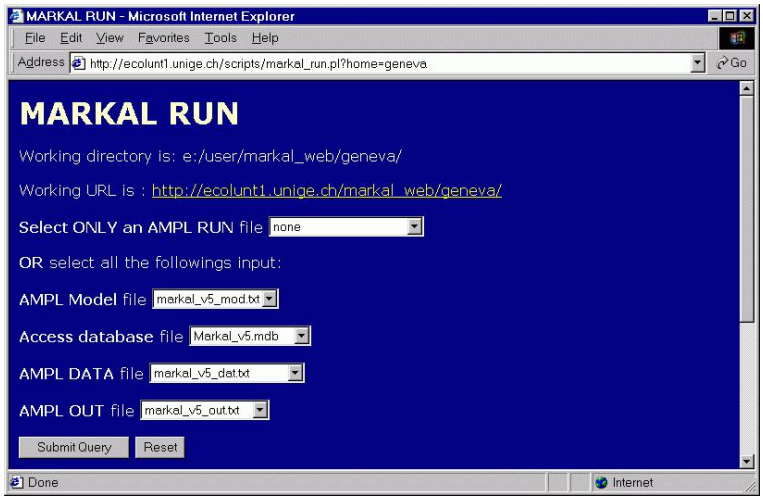



Figure 41: Selection of the input files.

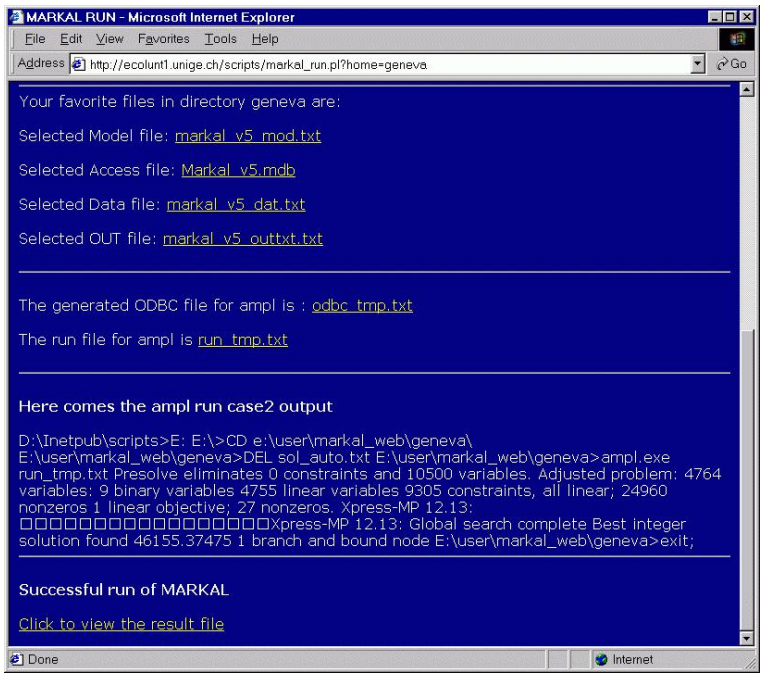



Figure 42: Result of the optimization.

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