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SMR 1585 - 1

WORKSHOP ON DESIGNING SUSTAINABLE ENERGY SYSTEMS
18 October - 5 November 2004

OVERVIEW OF MESSAGE MODEL

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These are preliminary lecture notes, intended only for distribution to participants.

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Overview of MESSAGE Model

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MESSAGE

- **Model for Energy Supply Strategy Alternatives and their General Environmental impacts**

Evolution of MESSAGE

- **Developed by International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria**

- **Häfele-Manne Model; 1974**
- **MESSAGE-I; 1978**
- **MESSAGE-II; 1984**
- **MESSAGE-III; 1992**
- **MESSAGE-IV;1998**
- **MESSAGE-V with user-interface; 2001**

Features of MESSAGE (1)

It is an energy supply model, representing the energy conversion and utilization processes of the energy system (or it's part) and their environmental impacts for an exogenously given demand of final energy;

It is used for development of medium-term strategies, the planning horizon being in the order of 30 years. The time scope is limited by the technology orientation of the approach, due to the uncertainties associated with future technological development. The energy system dynamics are modelled by multi period approach;

Features of MESSAGE (2)

It is an optimization model which from the set of existing and possible new technologies select the optimal in terms of selected criterion mix of technologies able to cover given country (or other) demand for various energy forms during the whole study period;

Criterion:

- **Cost minimization,**
- **Profit maximization,**
- **Multi-objective optimization.**

Features of MESSAGE (3)

The mathematical method used in the model can be:

- **Linear programming,**
- **Mixed-integer programming,**
- **Non-linear programming,**

Model into account demand variations of various final energy forms during day, week and seasons, as well as different technological and political constrains of energy supply;

Model is an energy and environmental model, enabling the user to carry out integrated analysis of the energy sector development and its environmental impacts;

Features of MESSAGE (4)

The representation of the energy system in the model is based on a network concept. The activities and relationships of an energy system are described as an oriented graph, depicting the energy chain starting from extraction or supply of primary energy, passing through the several energy conversion processes (e.g. electricity generation, transmission and distribution) in order to satisfy the demand for final energy in the industry, household, transportation and other economy branches. Using the notation of oriented graph, the links of the graph represent technologies or transportation and allocation process of energy, whilst the nodes represent energy forms (like electricity, oil and gas).

Features of MESSAGE (5)

The decision variables in the model formulation are the energy flows and the equipment capacities of the several technologies in the different time periods. They are linked by capacity-flow constrains. The model variables are subject to a system of constraints, representing the structural and technological Properties of the energy system, the existing stock of equipment, the projected final energy demand, energy policy, restrictions, and the impact of the energy technologies on air pollution, emission control technologies and emission control policy restrictions.

Features of MESSAGE (6)

The technologies are represented by a set of parameters in the model database, which is transformed into the model's system of equations by a matrix generator programme. Such parameters are e.g. prices of primary energy curriers, investment, fixed and variable costs, of various technologies, energy conversion efficiencies, existing capacities, availability factors, emission factors and others.

Features of MESSAGE (7)

The model is applied by defining scenarios. Scenarios represent different hypotheses on important parameters, like the future fuel prices in the international market, the market penetration of new technologies, the market penetration of local and renewable energy sources, political decision on development of one or another type of technology, etc., in order to take into account uncertainties in the future.

Features of MESSAGE (8)

The application of the MESSAGE model results in a least-cost inter-temporal mix of primary energy, energy conversion and emission control technologies for each scenario. By analysing the results, “what if?” statements on the future energy supply structure can be made, and different strategies of utilization of various primary energy sources can be compared with respect to their emission reduction efficiencies and their impact on structure and economy of the energy system.

Areas of MESSAGE application

Preparation and analysis of sustainable energy system development scenarios;

Preparation of energy system expansion strategies;

Preparation and analysis of environmental strategies and environmental regulation;

Analysis of energy supply reliability issues;

Modeling of energy and emission trading;

Other areas on global, regional, national or utility level.

Steps in modeling of energy system

Definition of object for analysis

Preparation of energy flow network

Collection of necessary initial information

Definition of load regions

Creation of model data bases (TDB and ADB)

Preparation of scenarios to be analyzed (Scenario DB)

Matrix generation

Optimization

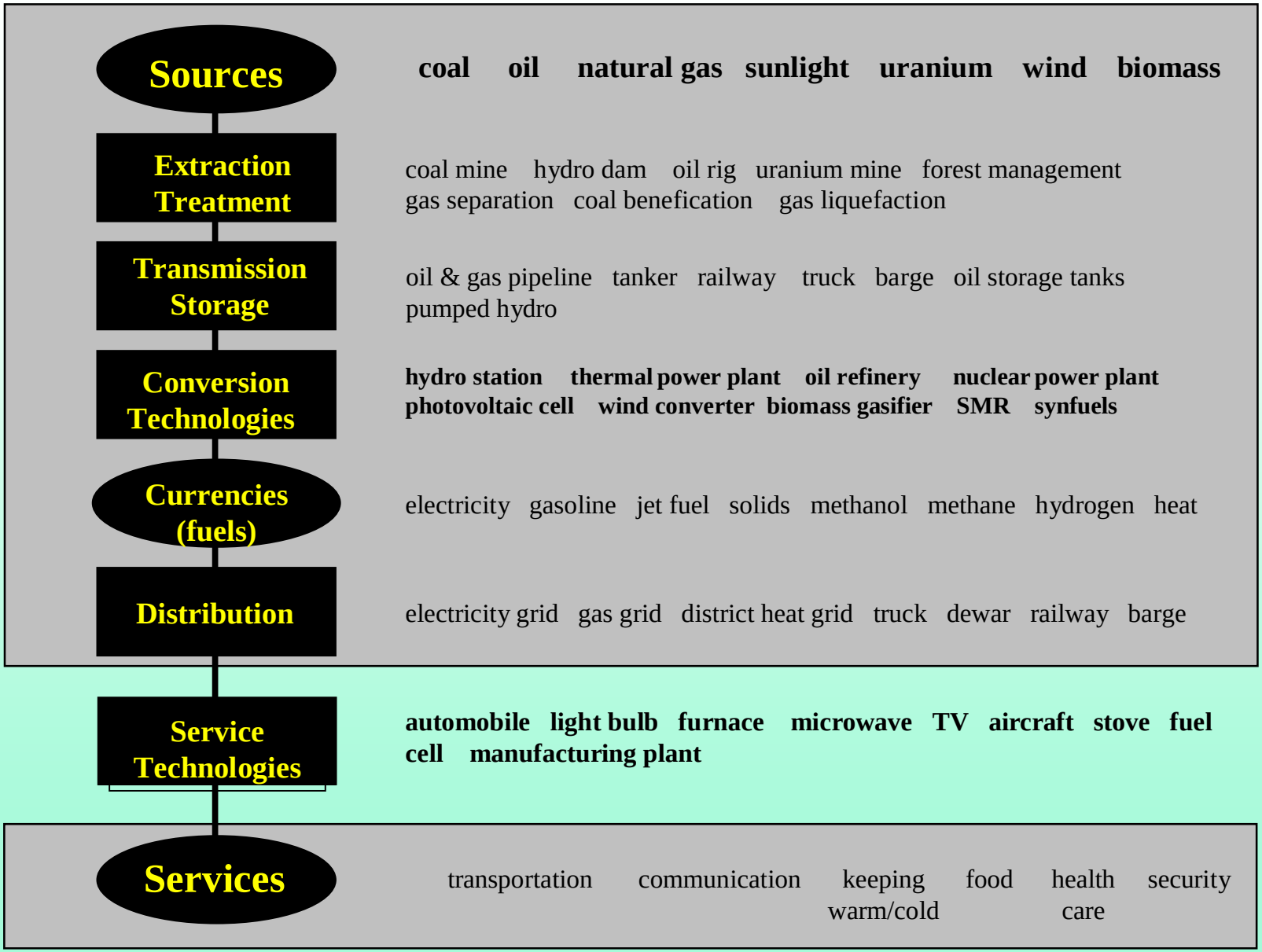
Review of results

Definition of object for analysis

MESSAGE models the material or energy flow from resources to demand (so called “energy chain”)

If energy system is concern, MESSAGE, depending on user needs can represent entire energy system or it’s part

Definition of object for analysis



Preparation of energy flow network

The key elements, based upon which MESSAGE builds energy system, are:

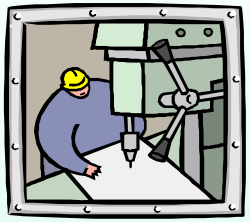
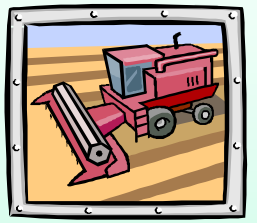
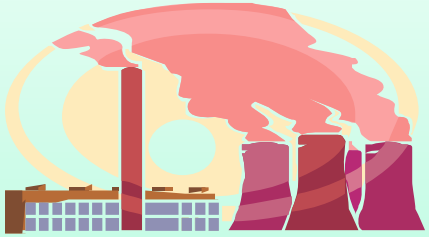
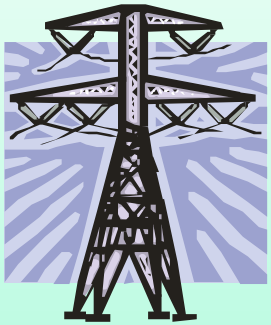
- **Energy forms/energy levels**
- **Technologies linking energy forms at various levels**
- **Relations which can be defined between energy forms, among various factors describing technologies**

Preparation of energy flow network

- **Any process, e.g., extraction, processing, conversion, transformation, transportation, distribution of energy can be represented as a "technology" in MESSAGE**
- **A set of technology parameters were built in MESSAGE data base to allow the users to represent various kinds of technologies**
- **A technology can be as simple as a electricity transmission line or as complicated as a refinery**

Energy Technologies

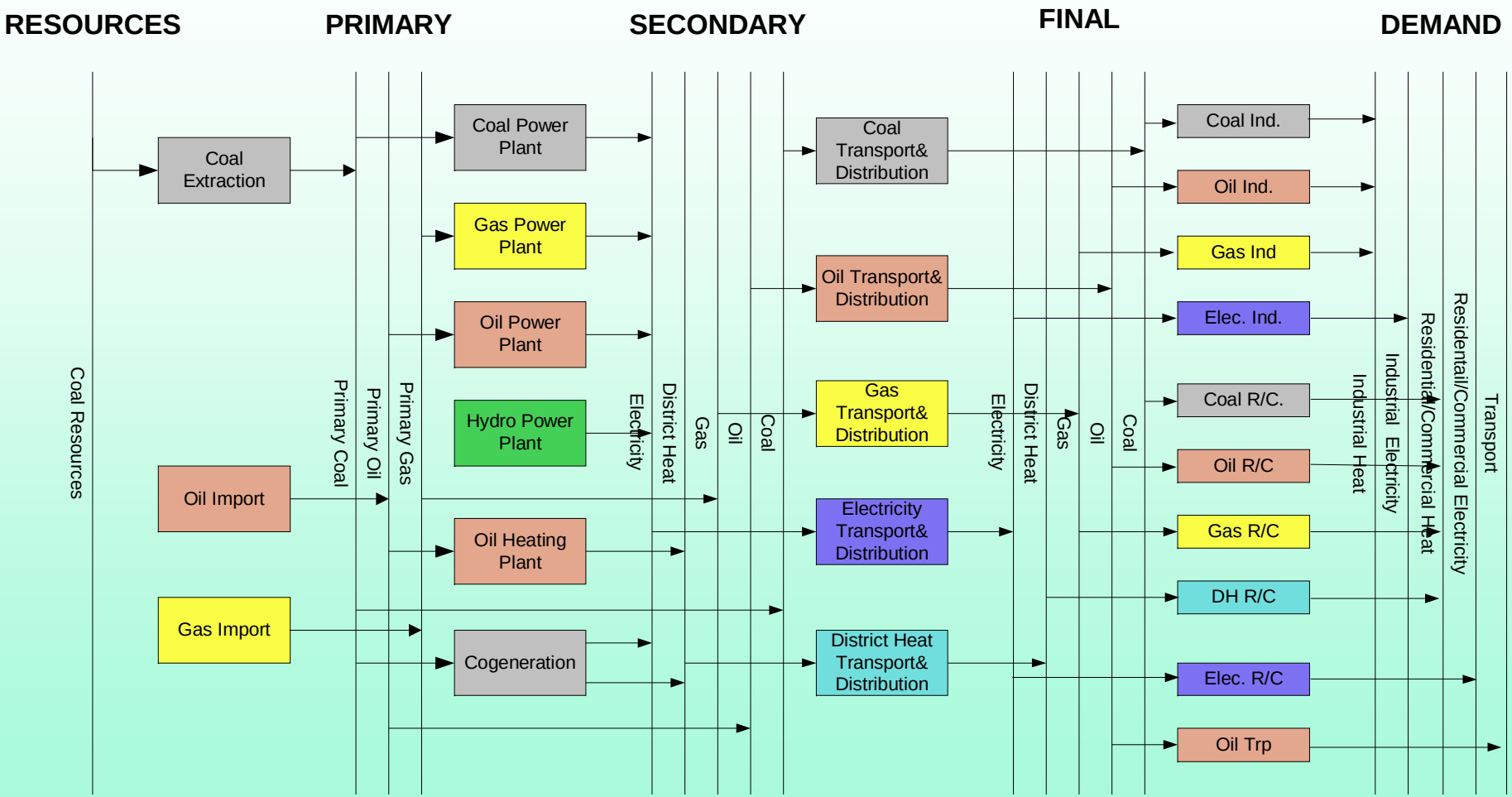


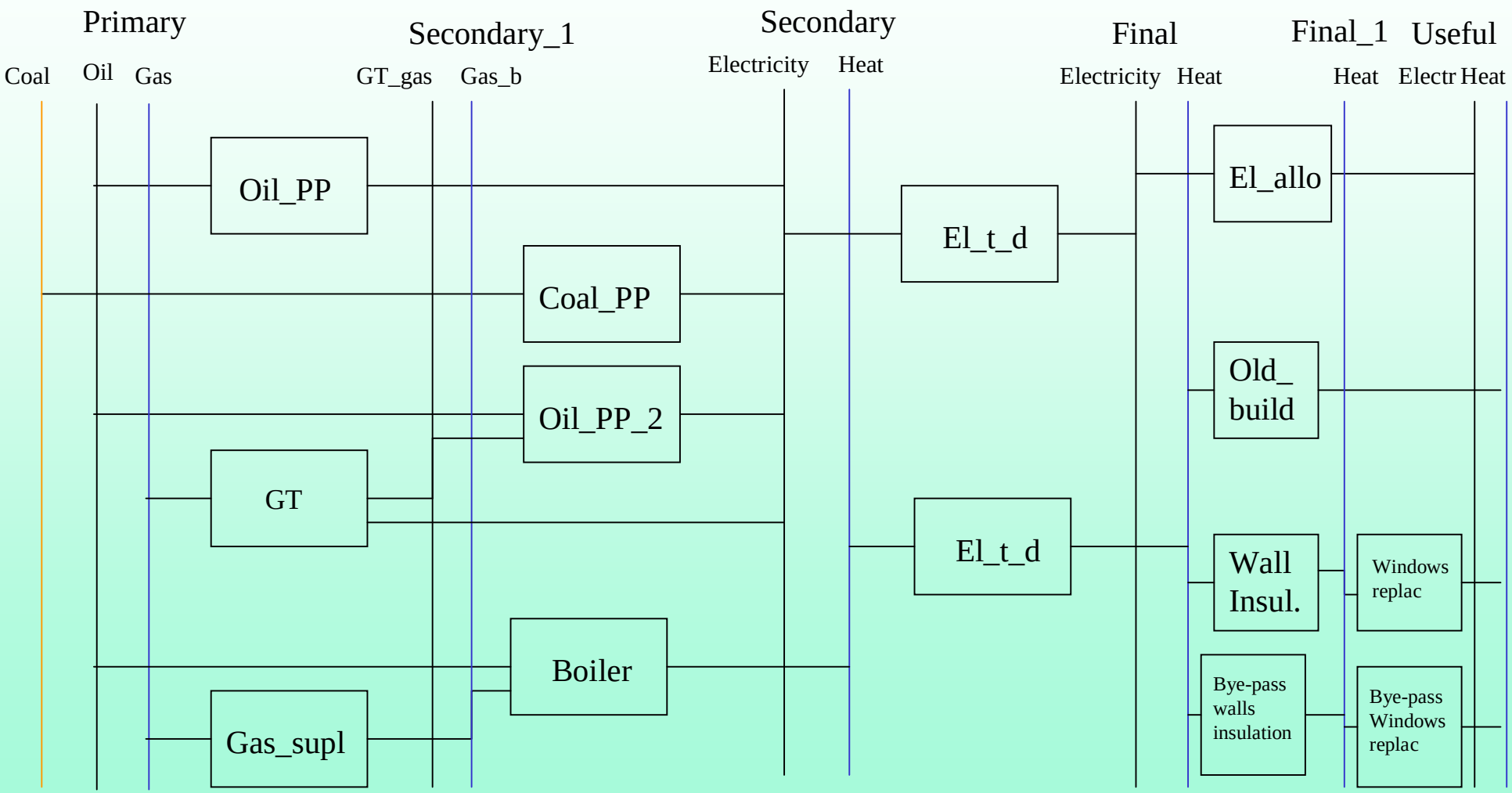




Preparation of energy flow network



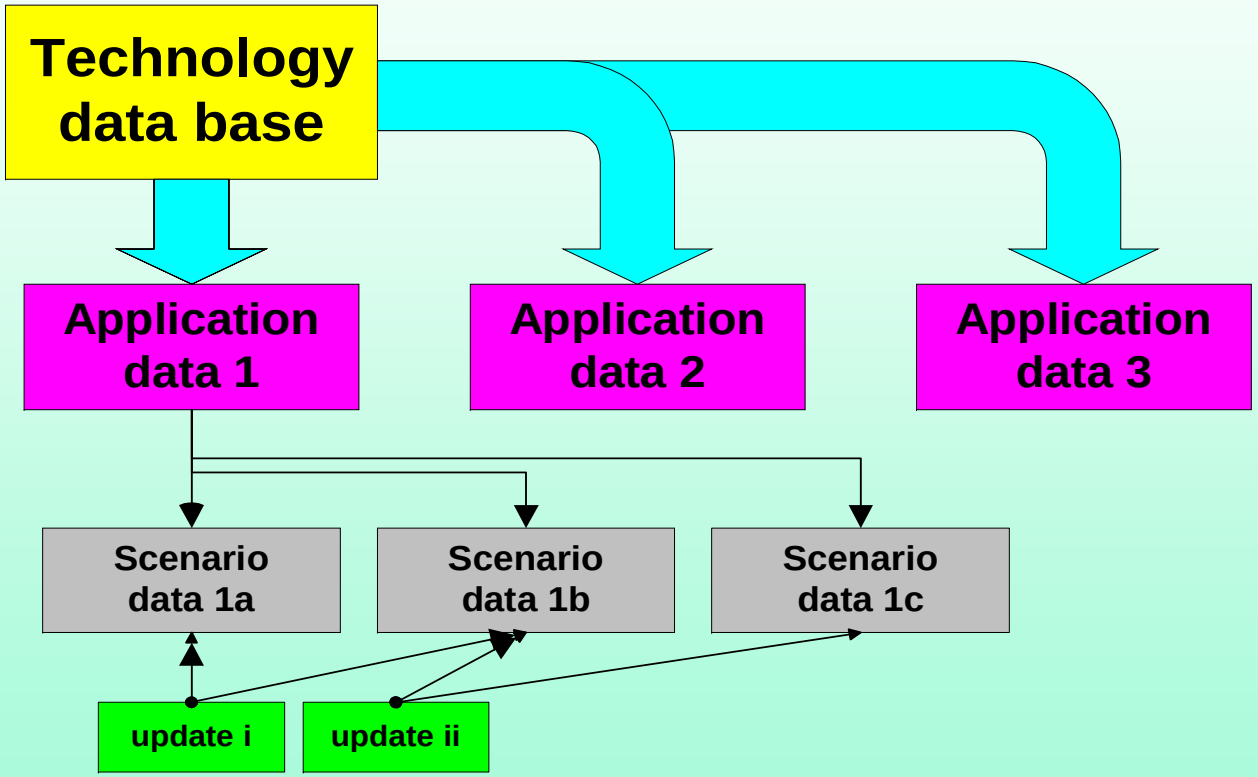
Preparation of energy flow network (fraction)



Collection of necessary initial information

- **Technical**
- **Economic**
- **Environmental and parameters used in relations with other technologies**
- **Parameters in MESSAGE are dynamic: they can change over time (seasonal and over year)**
- **Information should be adjusted to the network of energy system**

Data bases in MESAGE



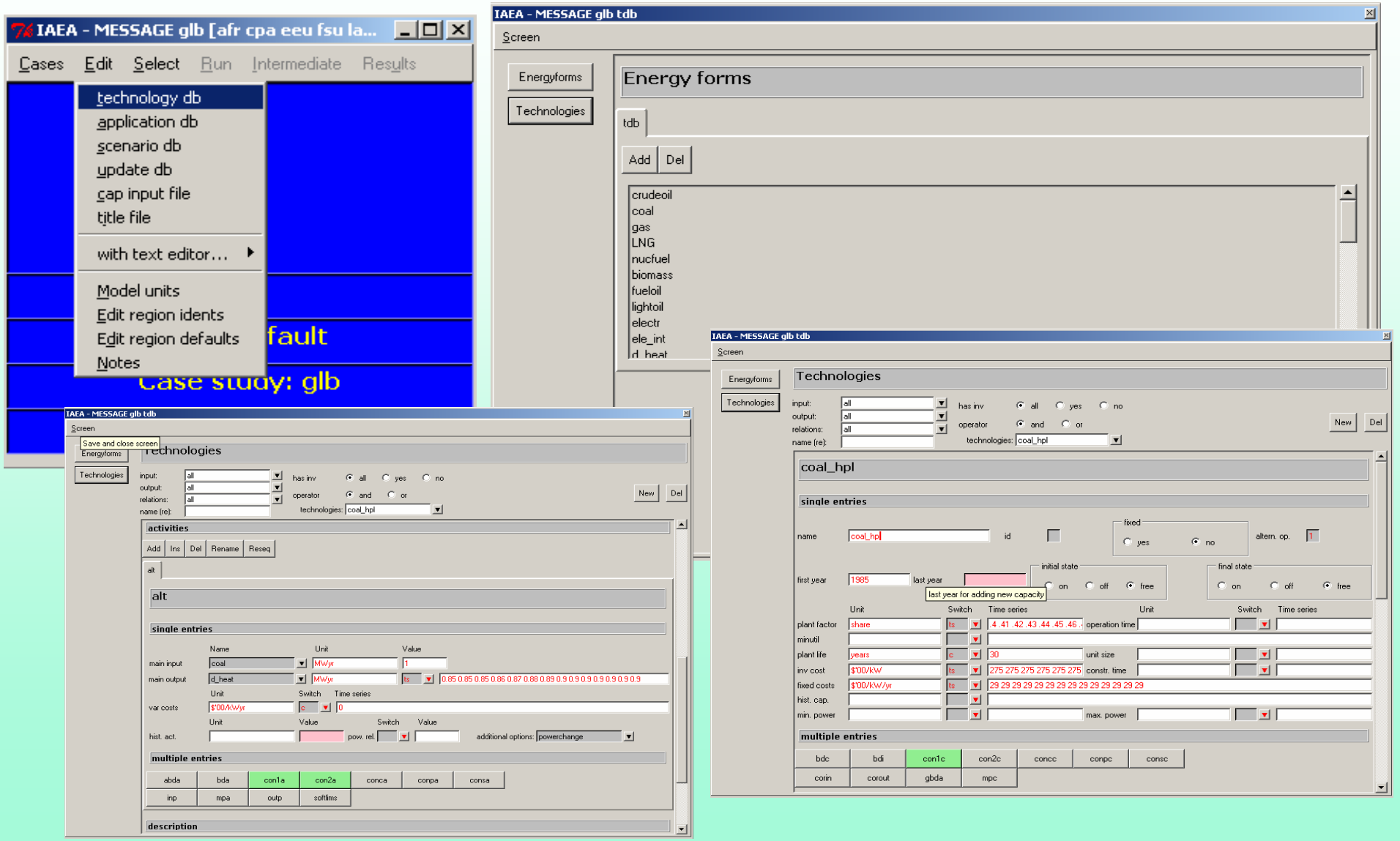
TDB:
Technical information on technologies

ADB:
Application Data Base: Regional Information

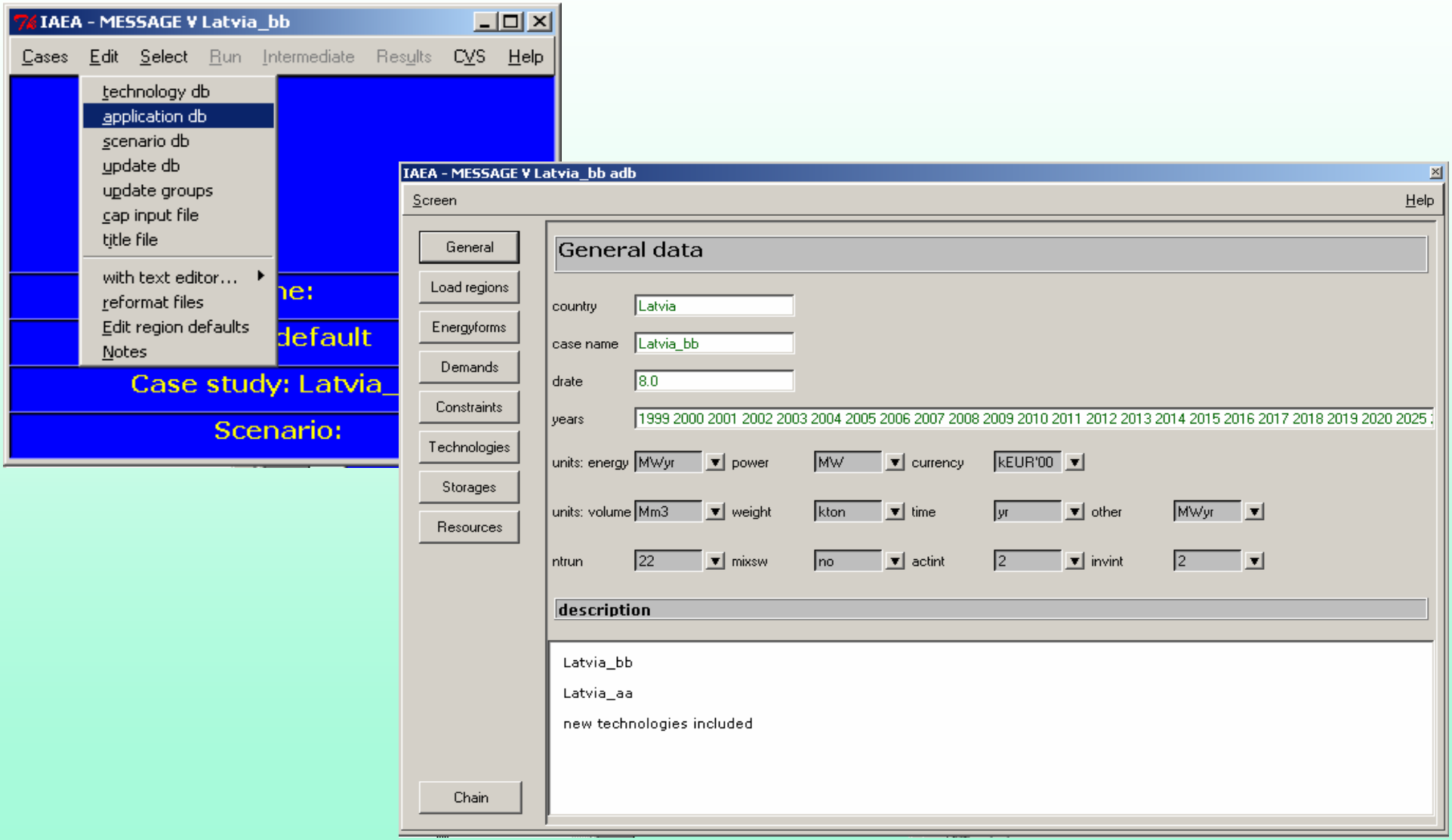
LDB:
Local Data Base: Scenario Information

UPD:
Update Files: Special cases

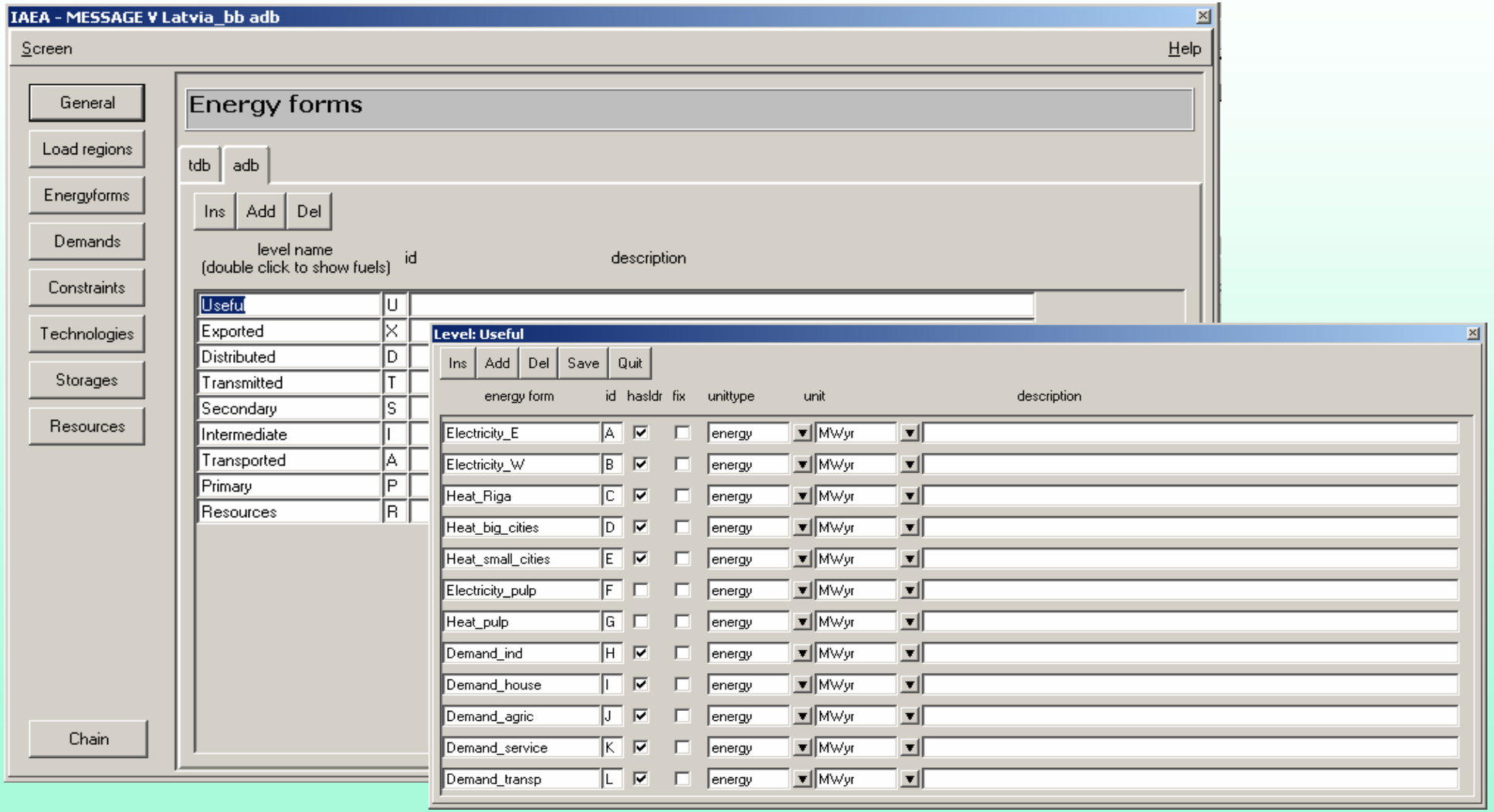
Creation of model data base (TDB)



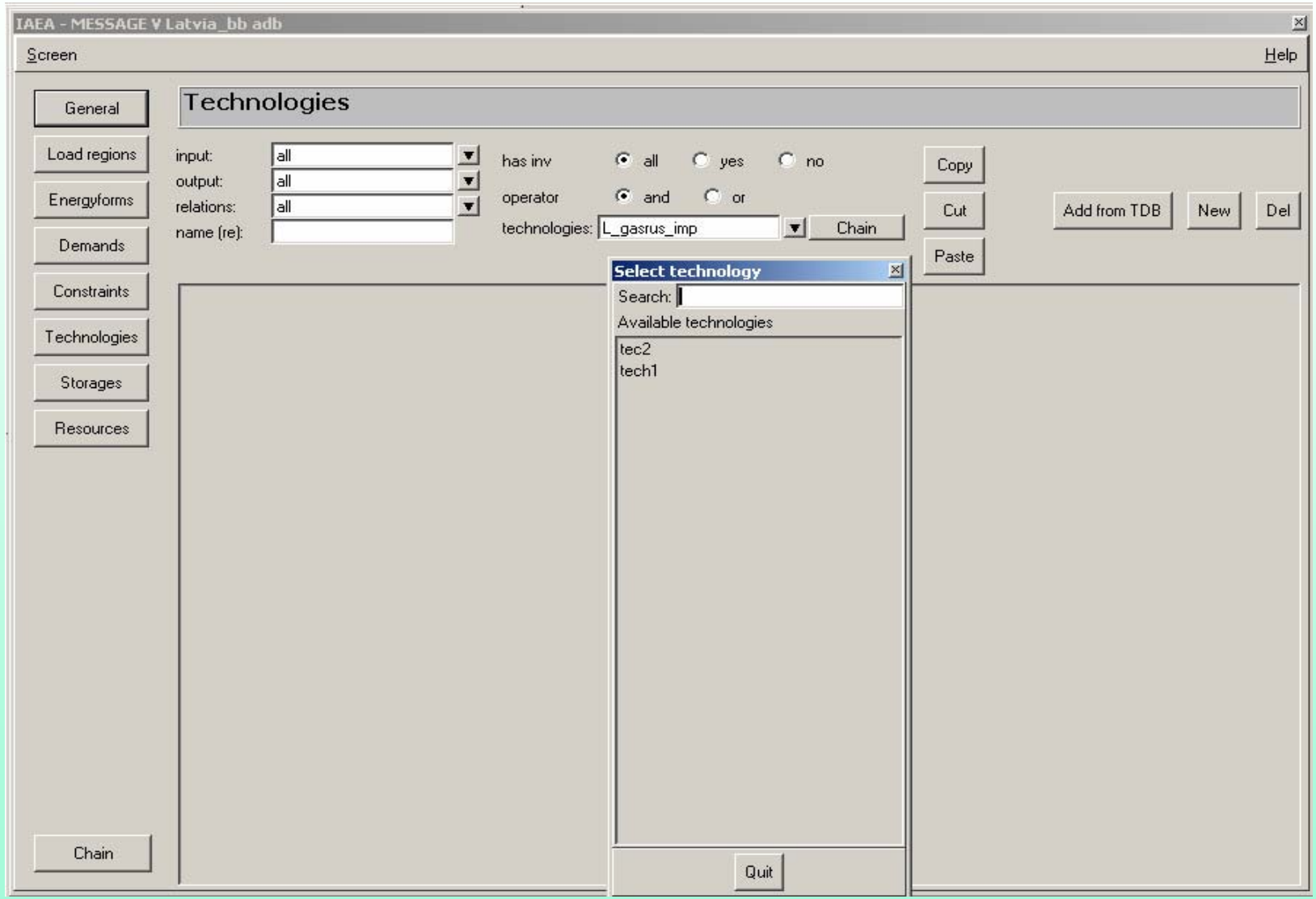
Creation of model data base (ADB)



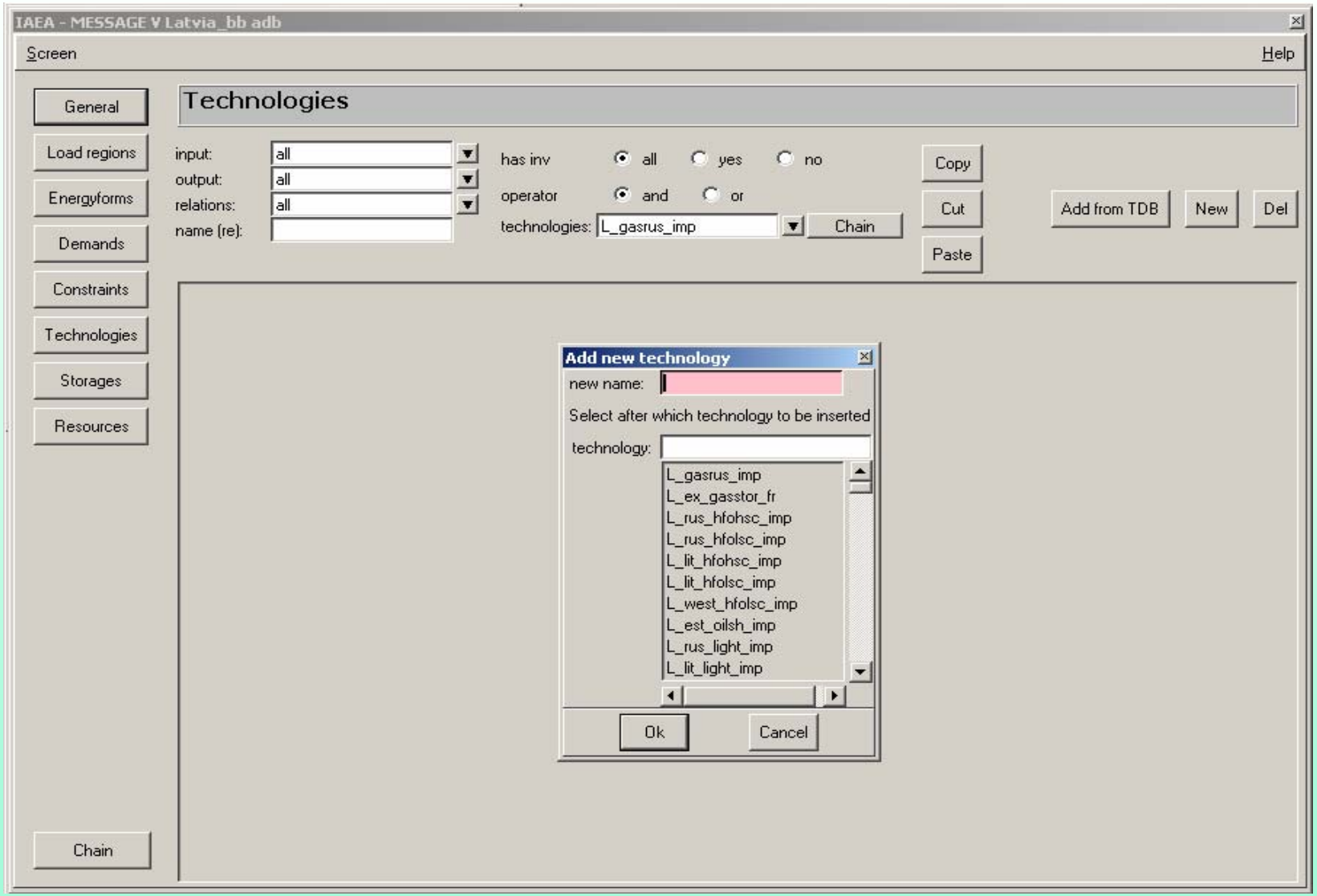
Creation of model data base (ADB)



Creation of model data base (ADB)



Creation of model data base (ADB)



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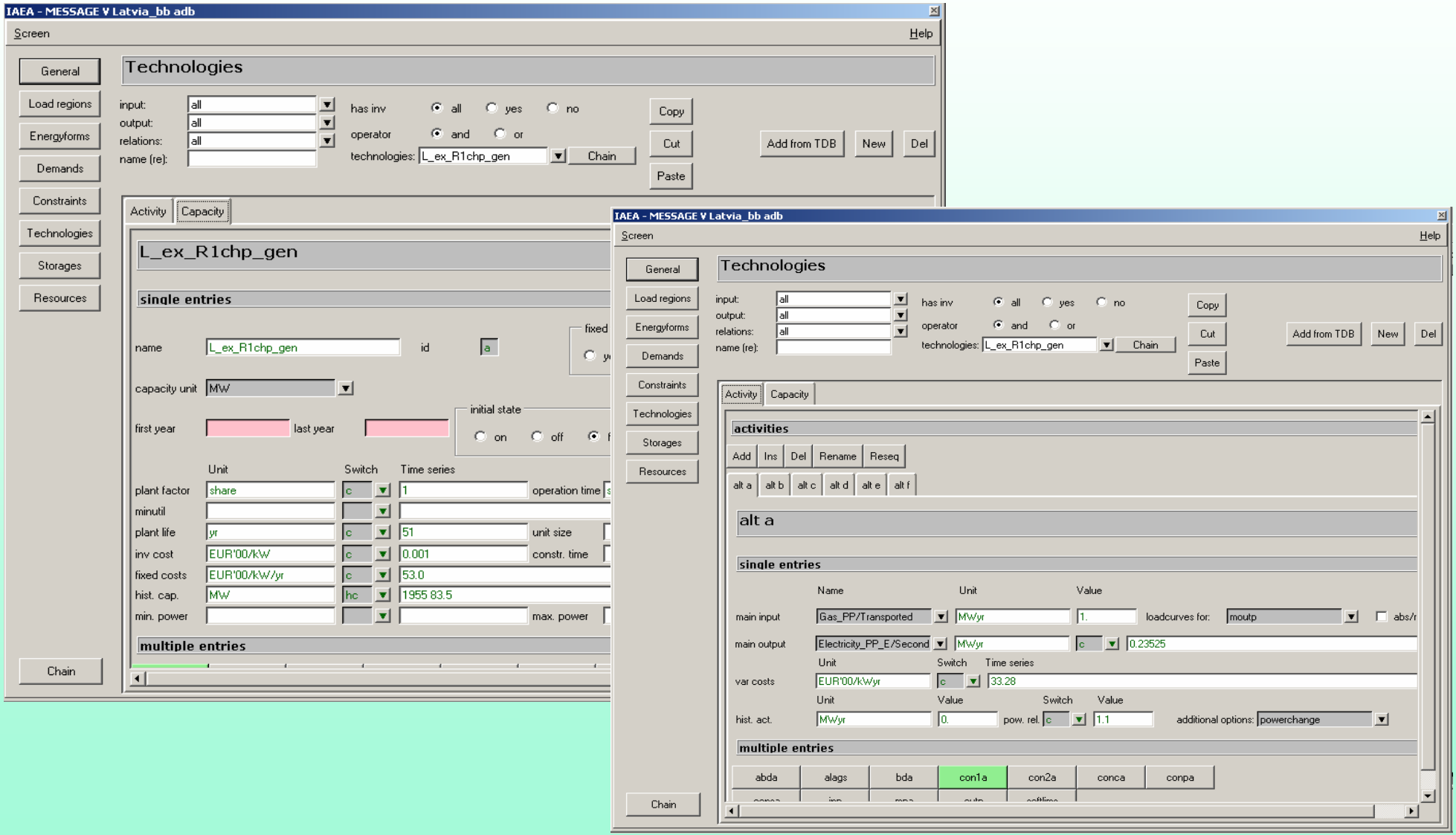
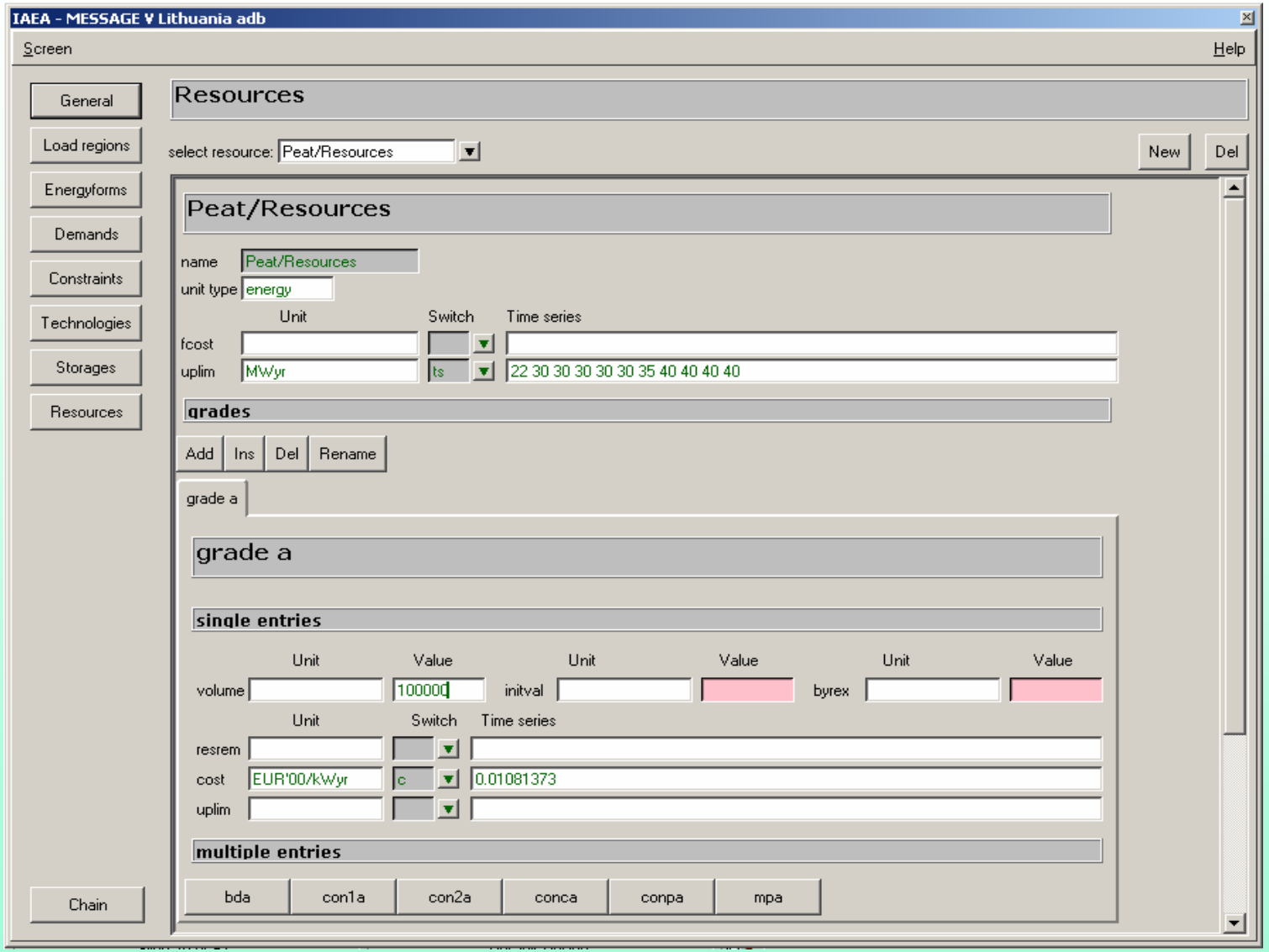
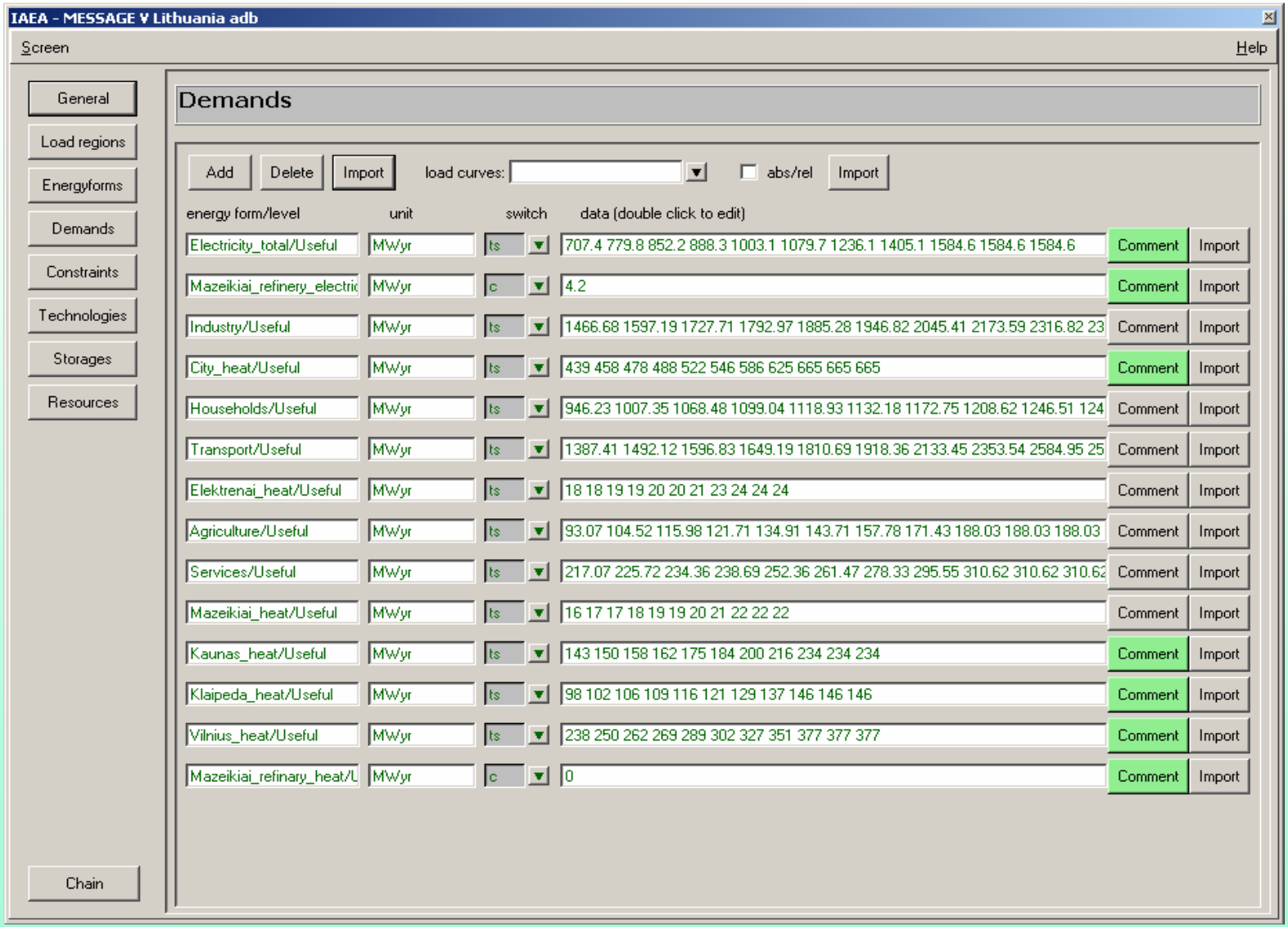


Creation of model data base (ADB)



Creation of model data base (ADB)



Definition of load regions

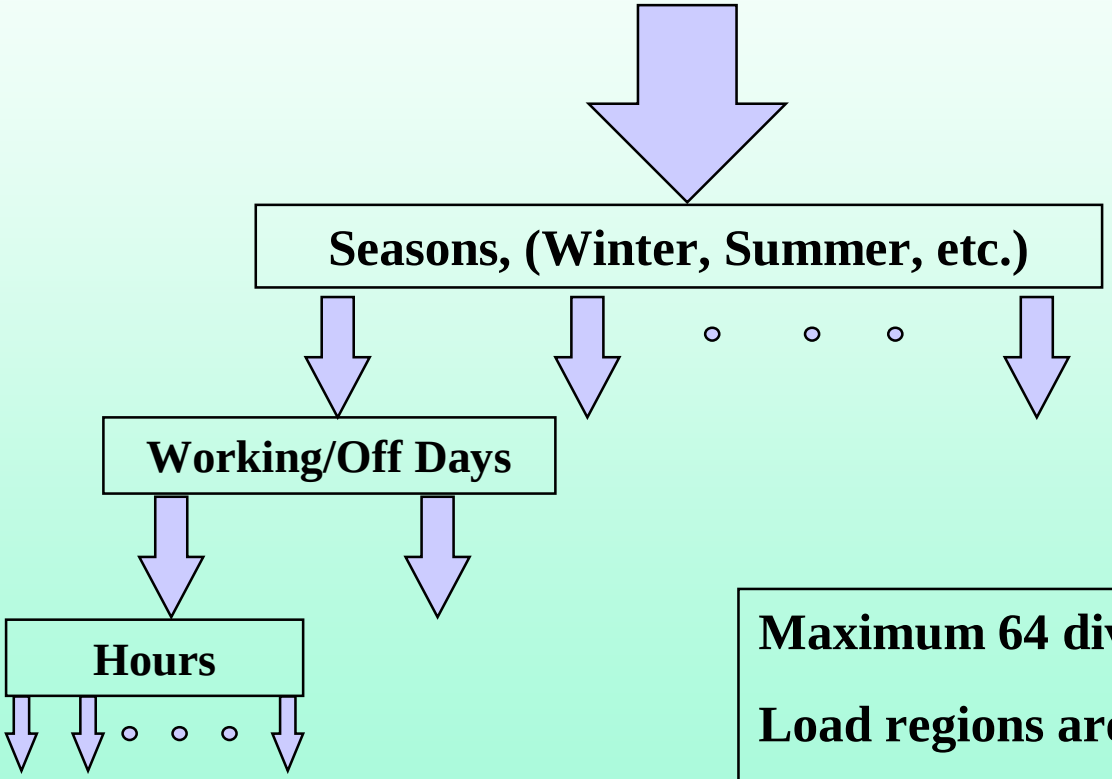
- **Demand for energy fuels is an input to MESSAGE. It must be defined exogenously by other models e.g., MAED**
- **MESSAGE allows to specify energy demand at any level**
- **MESSAGE can represent seasonal variation of energy demand**

Definition of load regions

- **Variation of energy demand during a year can be represented by load regions**
- **Other factors rather than energy demand should be taken into account when load regions are considered**
- **A year can be divided into up to 64 load regions**
- **Number of load regions may vary for different years**

Load Regions

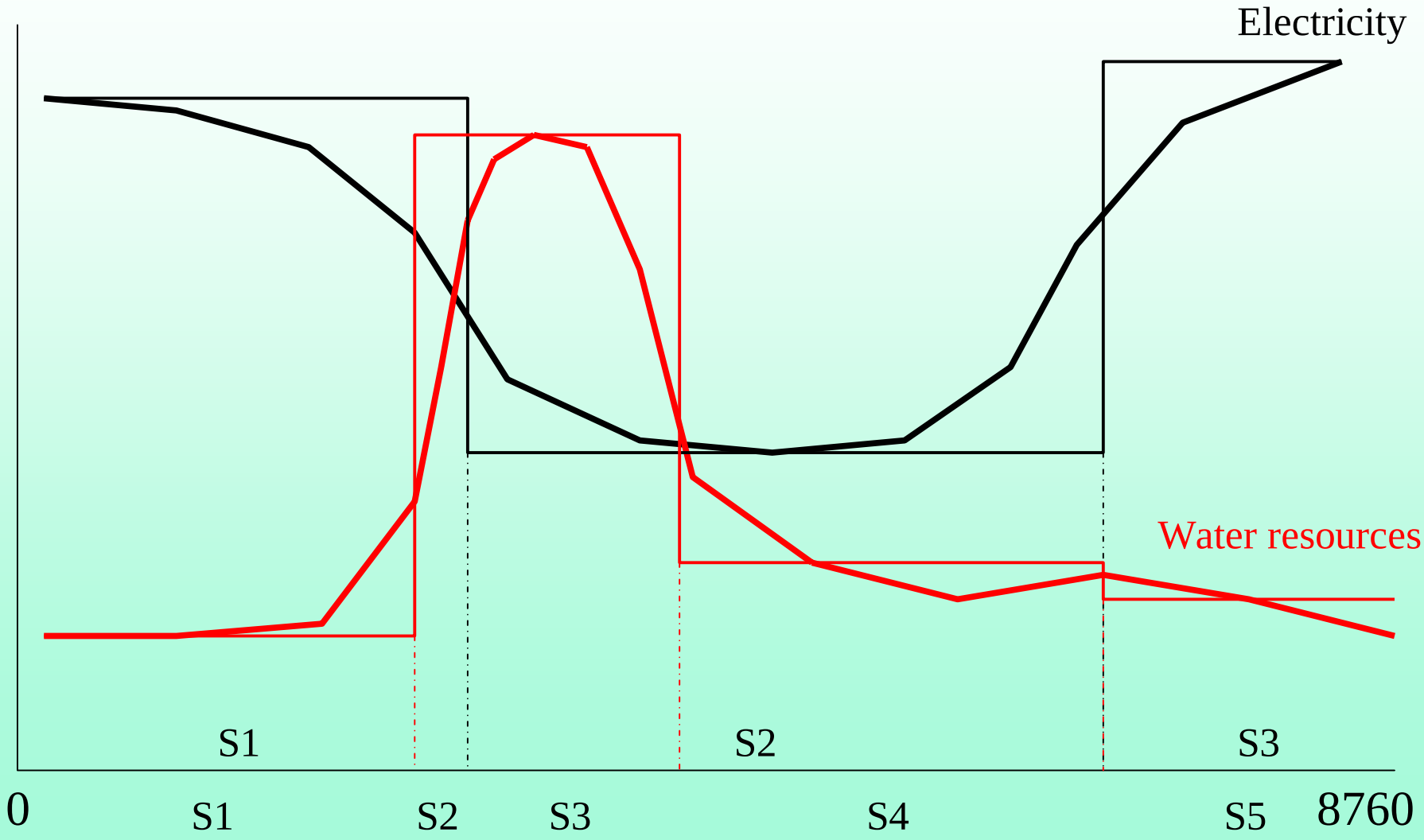
Seasonal Division of Year



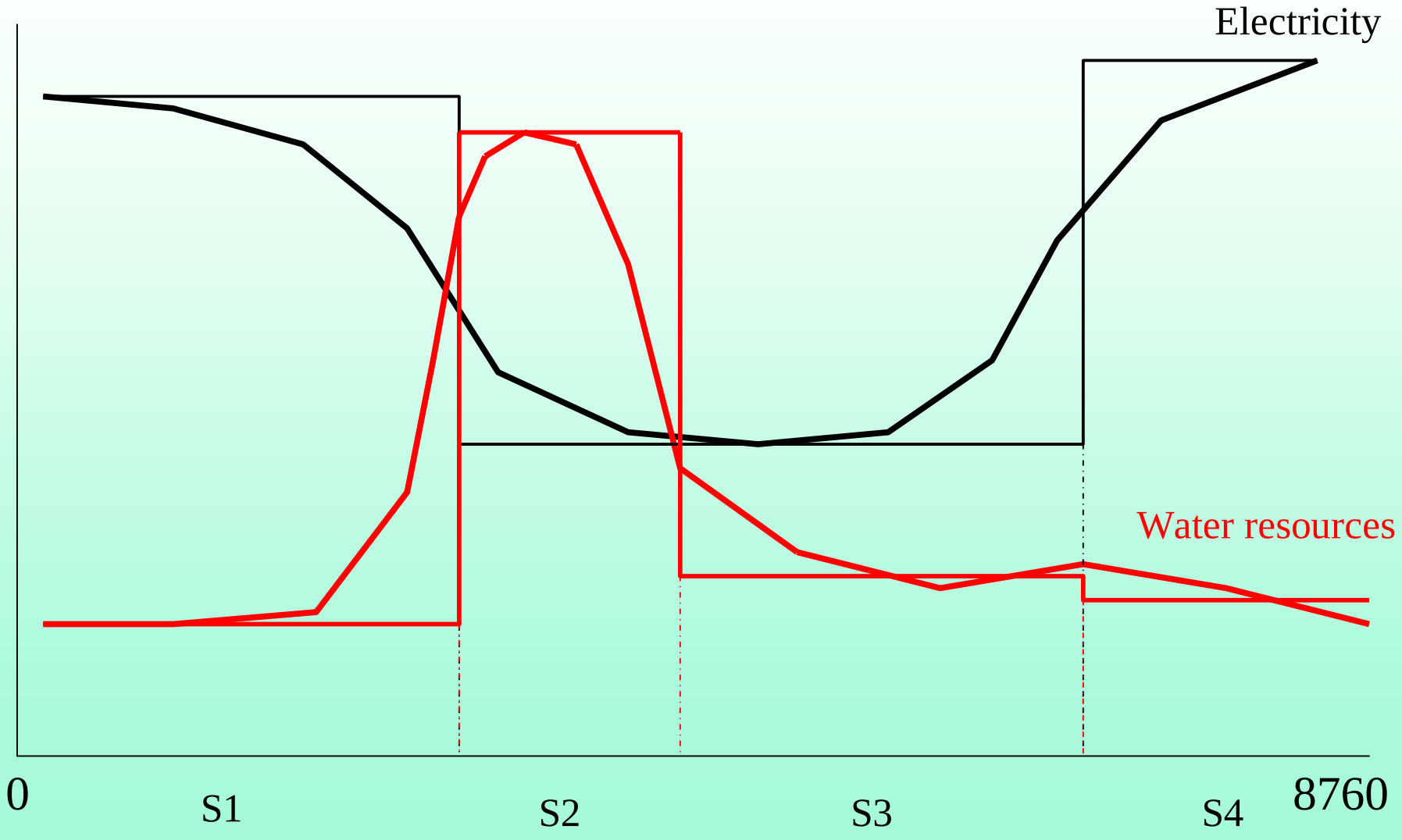
Maximum 64 divisions possible.

Load regions are the same for all energy curriers.

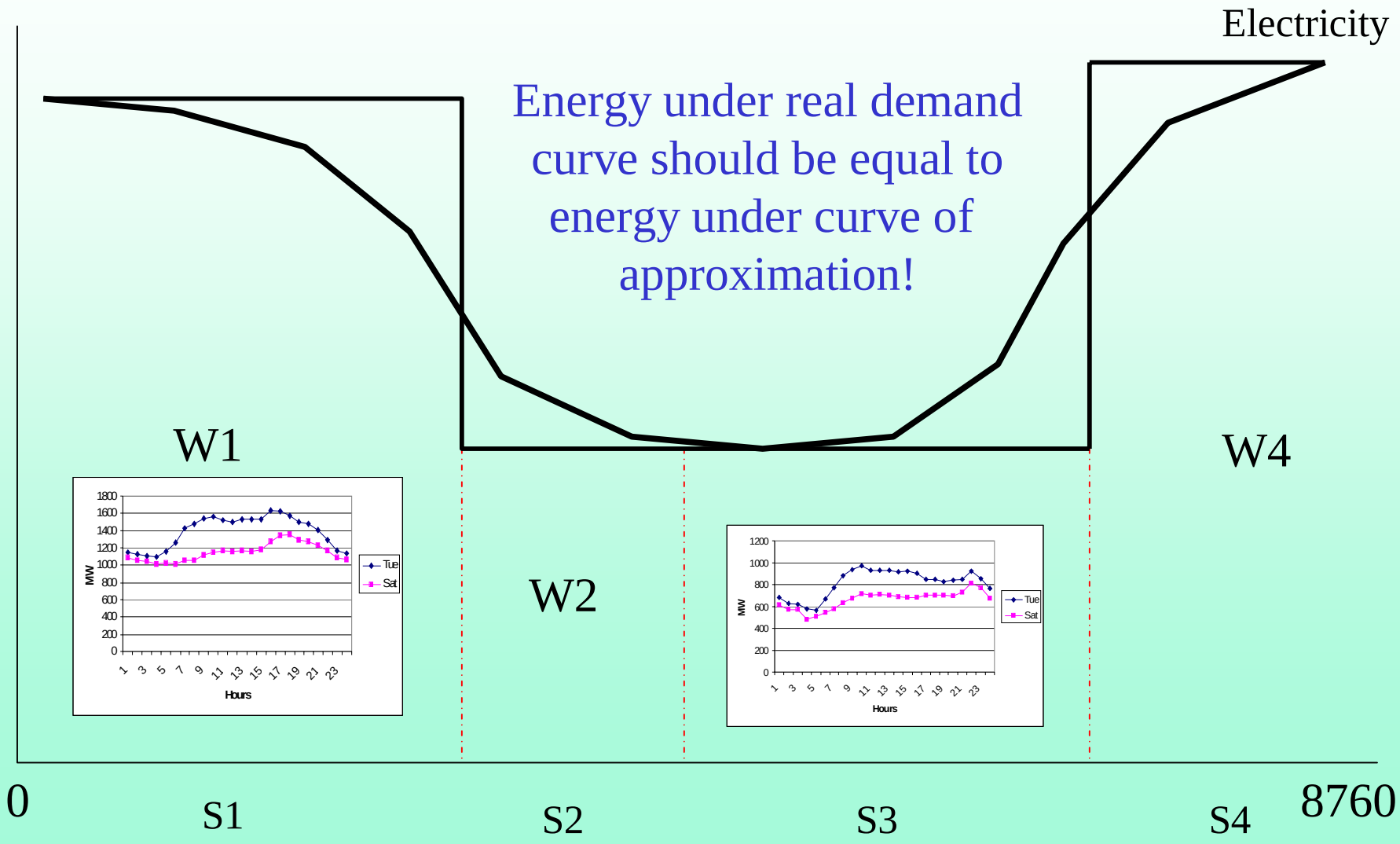
Definition of load regions
(Dividing into seasons)



Definition of load regions
(Reduction of seasons)

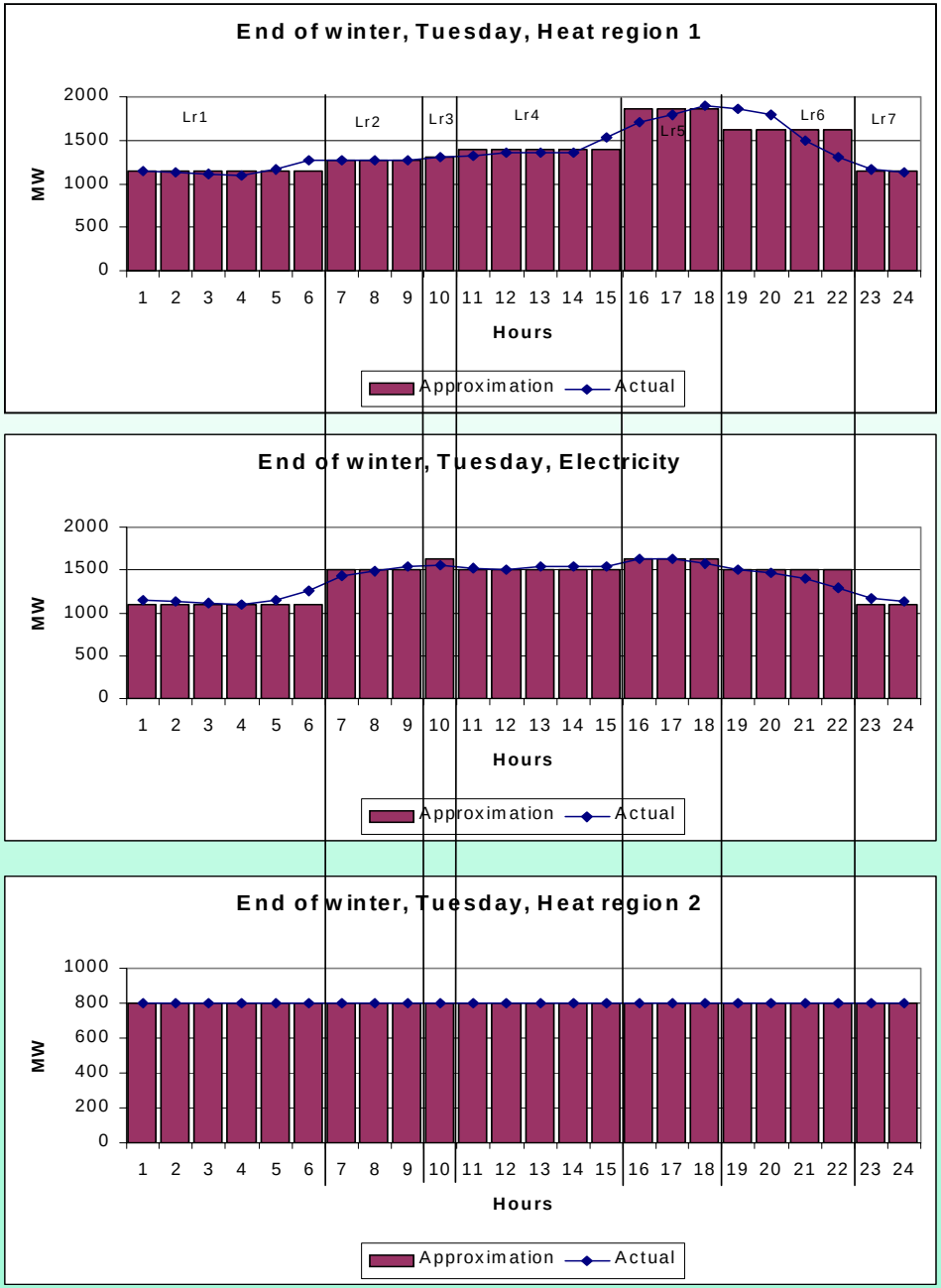


Definition of load regions
(Final representation of demand)



Definition of load regions (Final representation of demand)

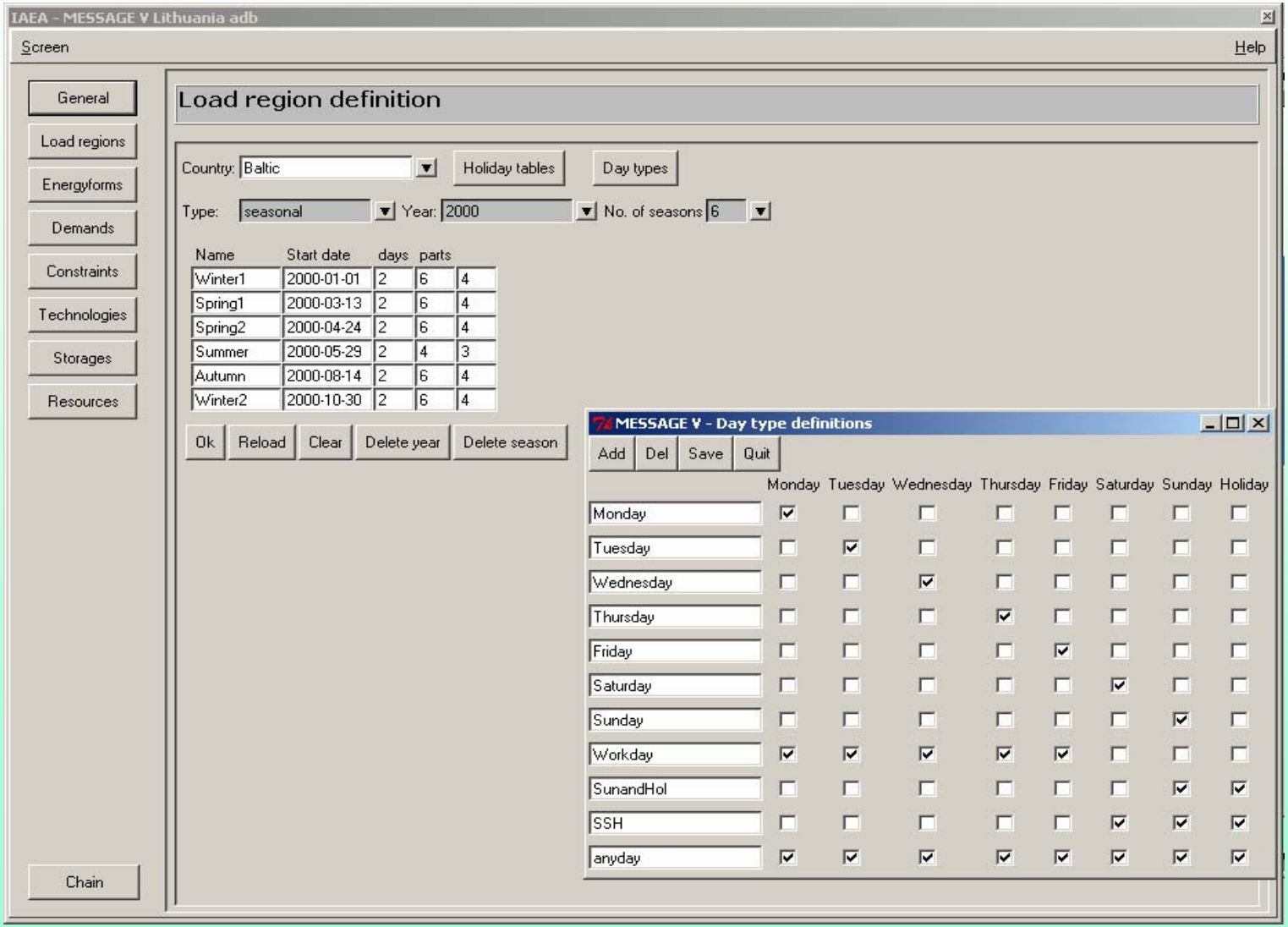
Load regions for whole model are the same!



Definition of load regions

(Creation of application data base)

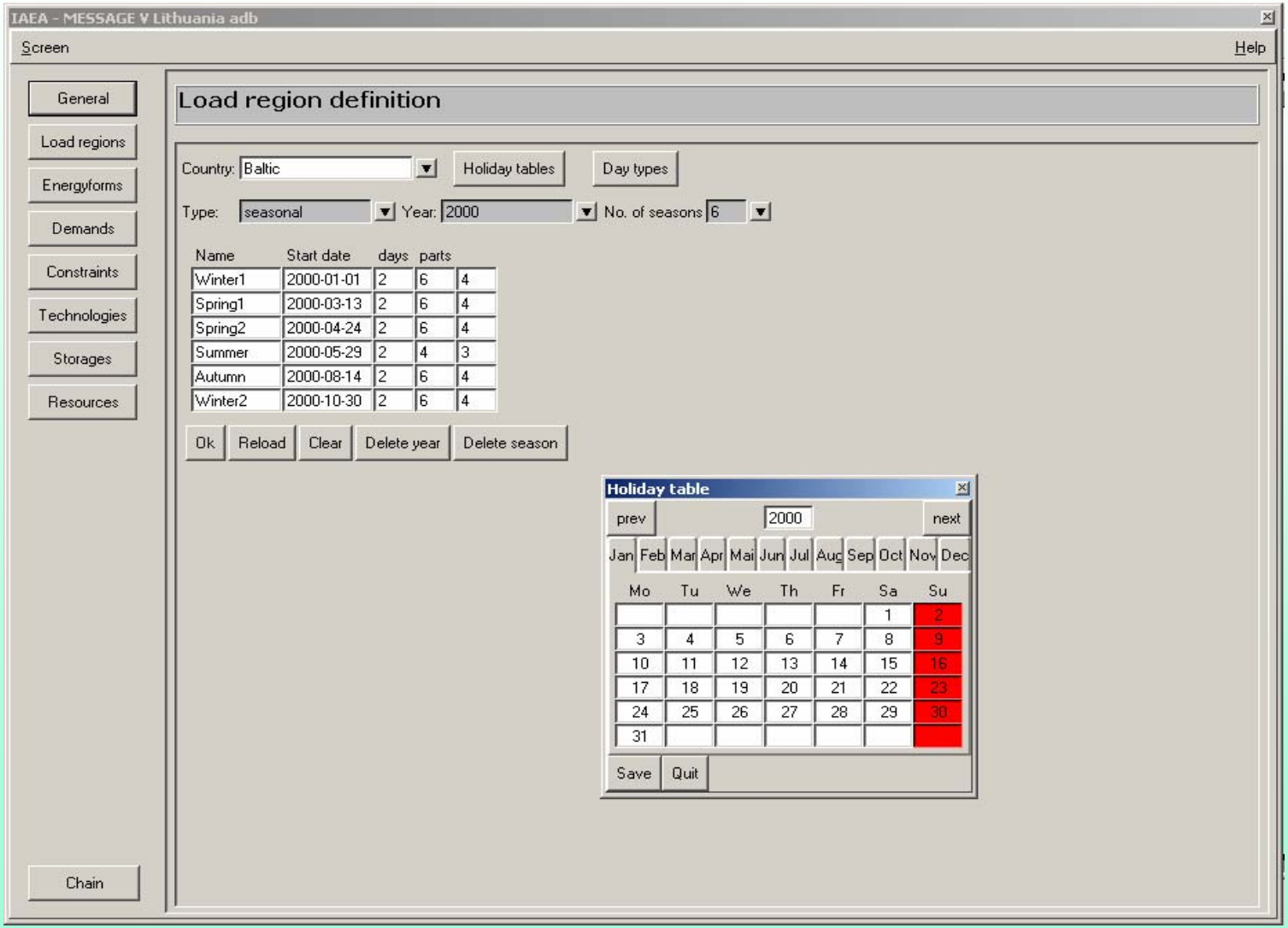
Definition of day types



Definition of load regions

(Creation of application data base)

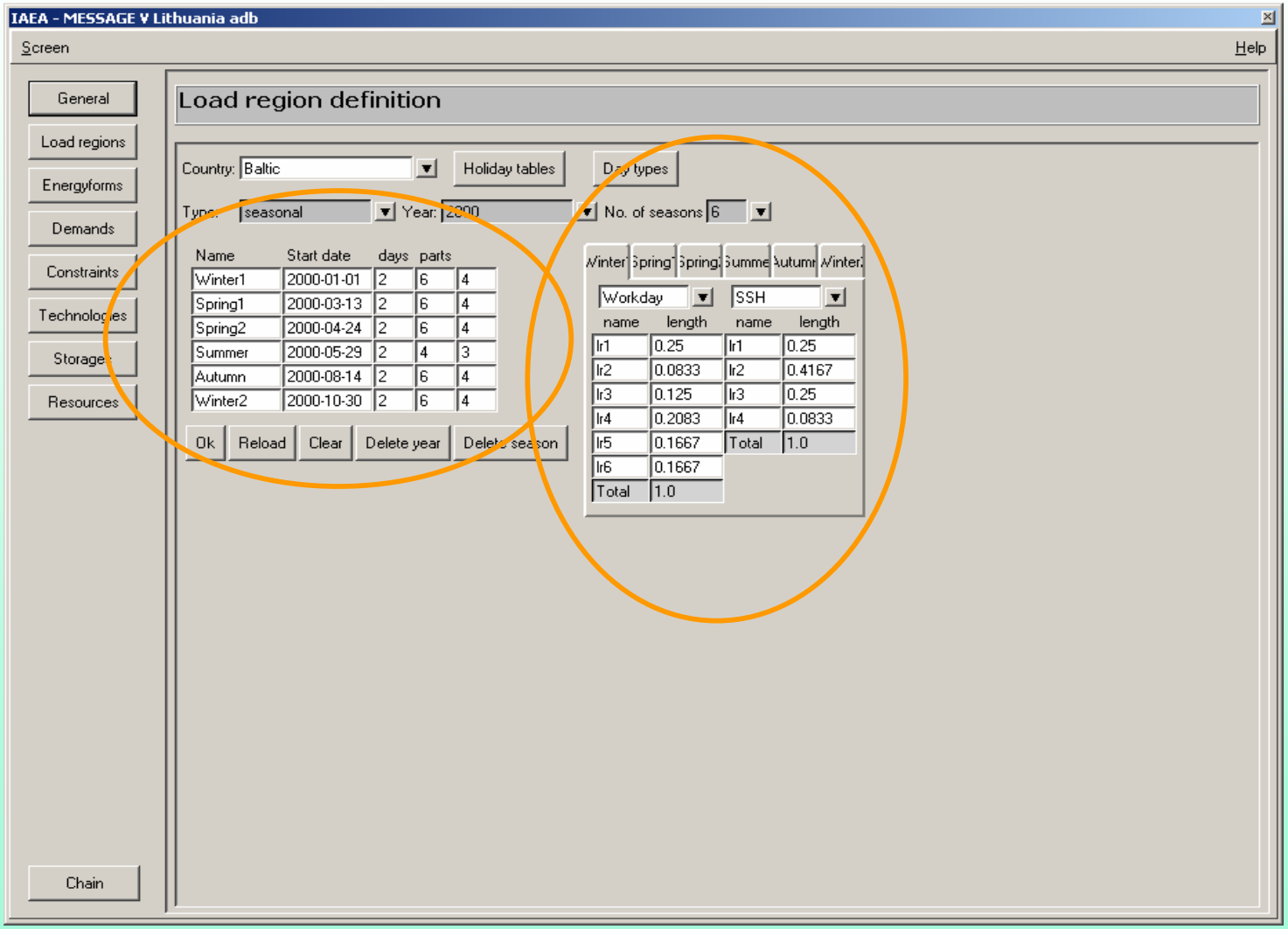
Definition of holidays



Definition of load regions

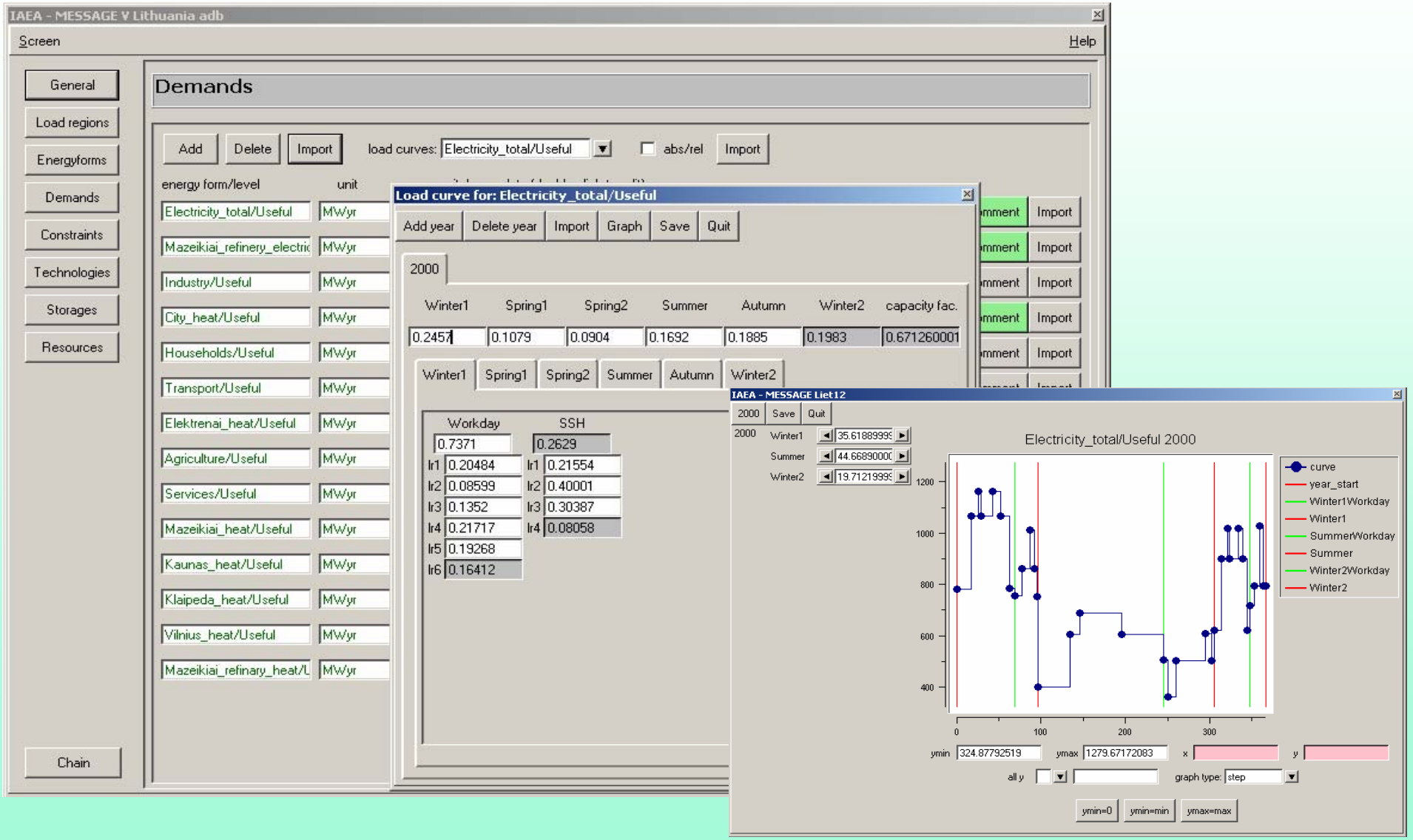
(Creation of application data base)

Parameters of load regions

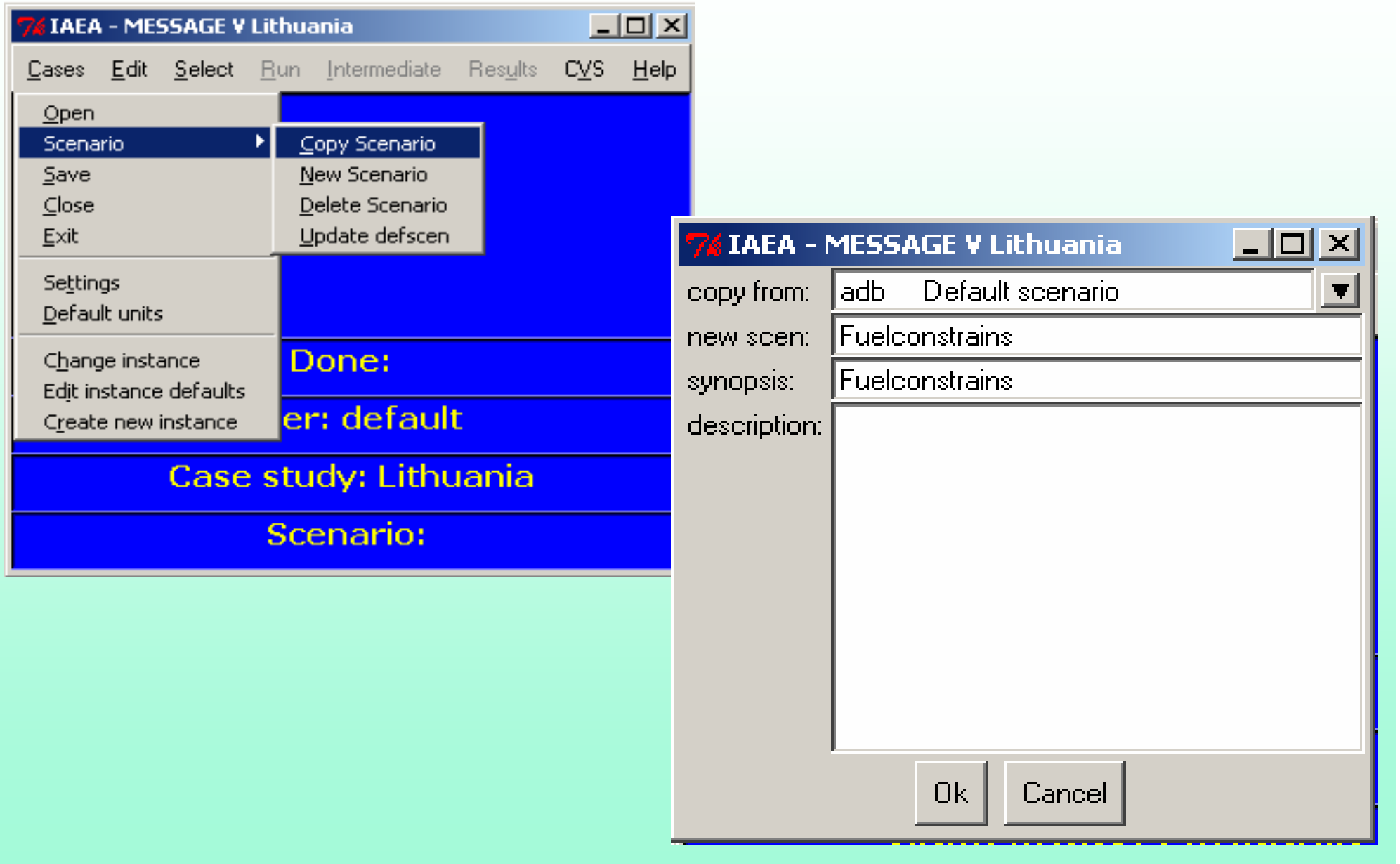


Definition of load regions

(Creation of application data base)



Preparation of scenarios to be analyzed (Scenario DB)



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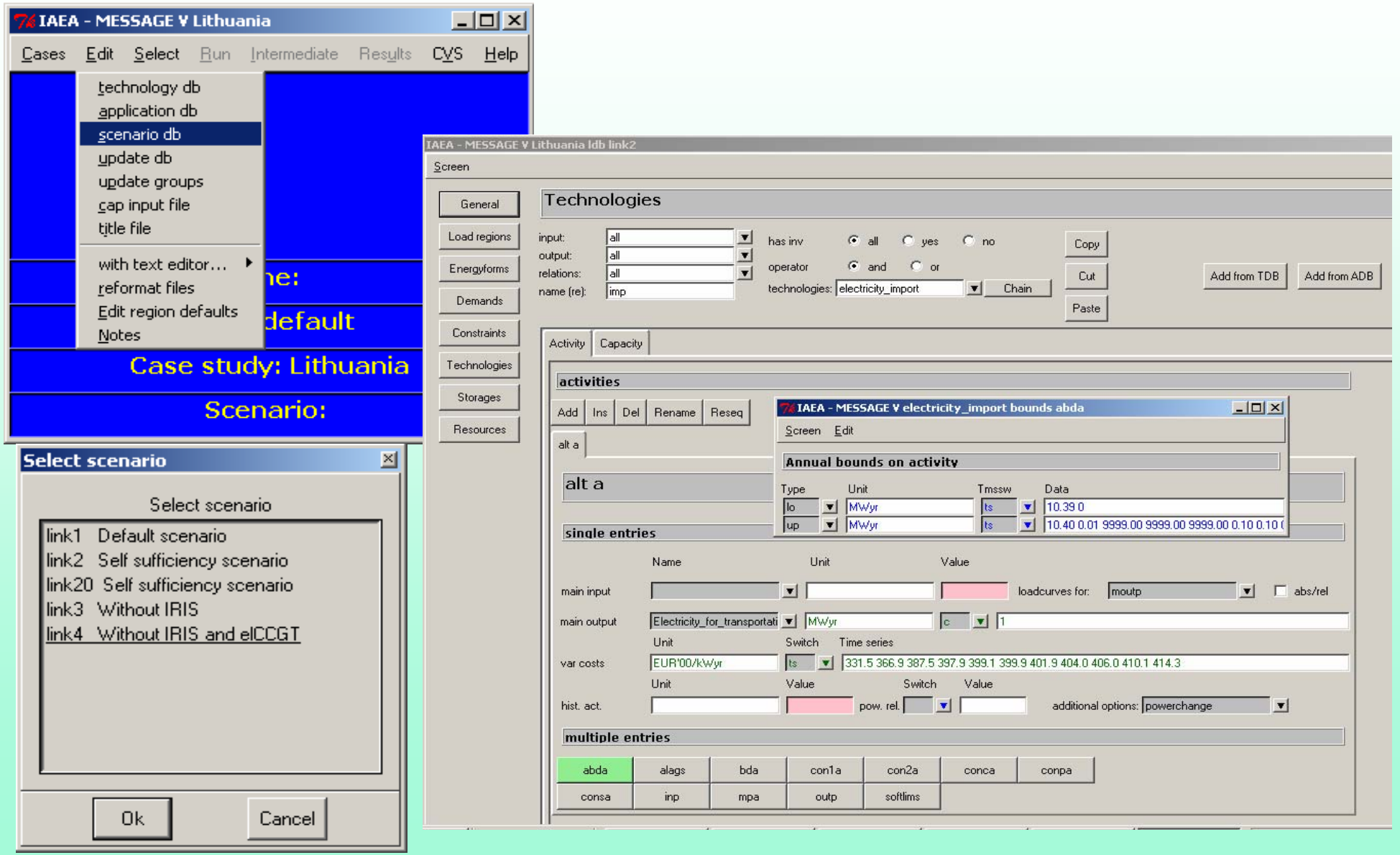
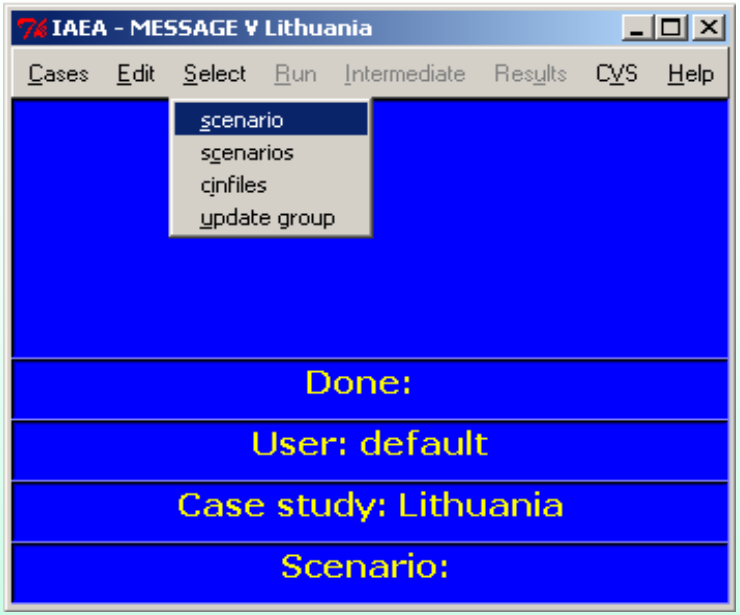
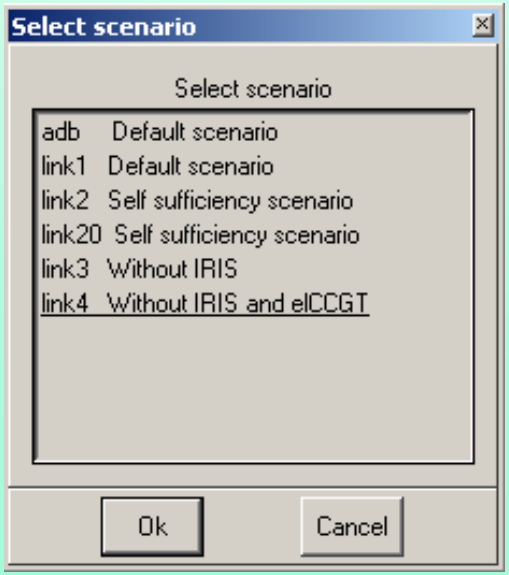
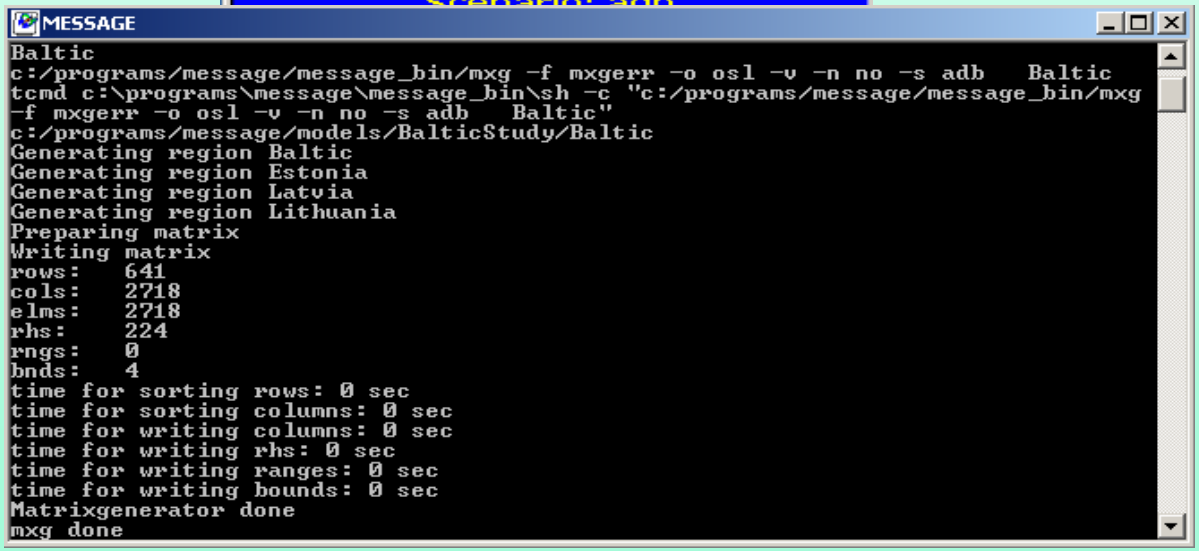


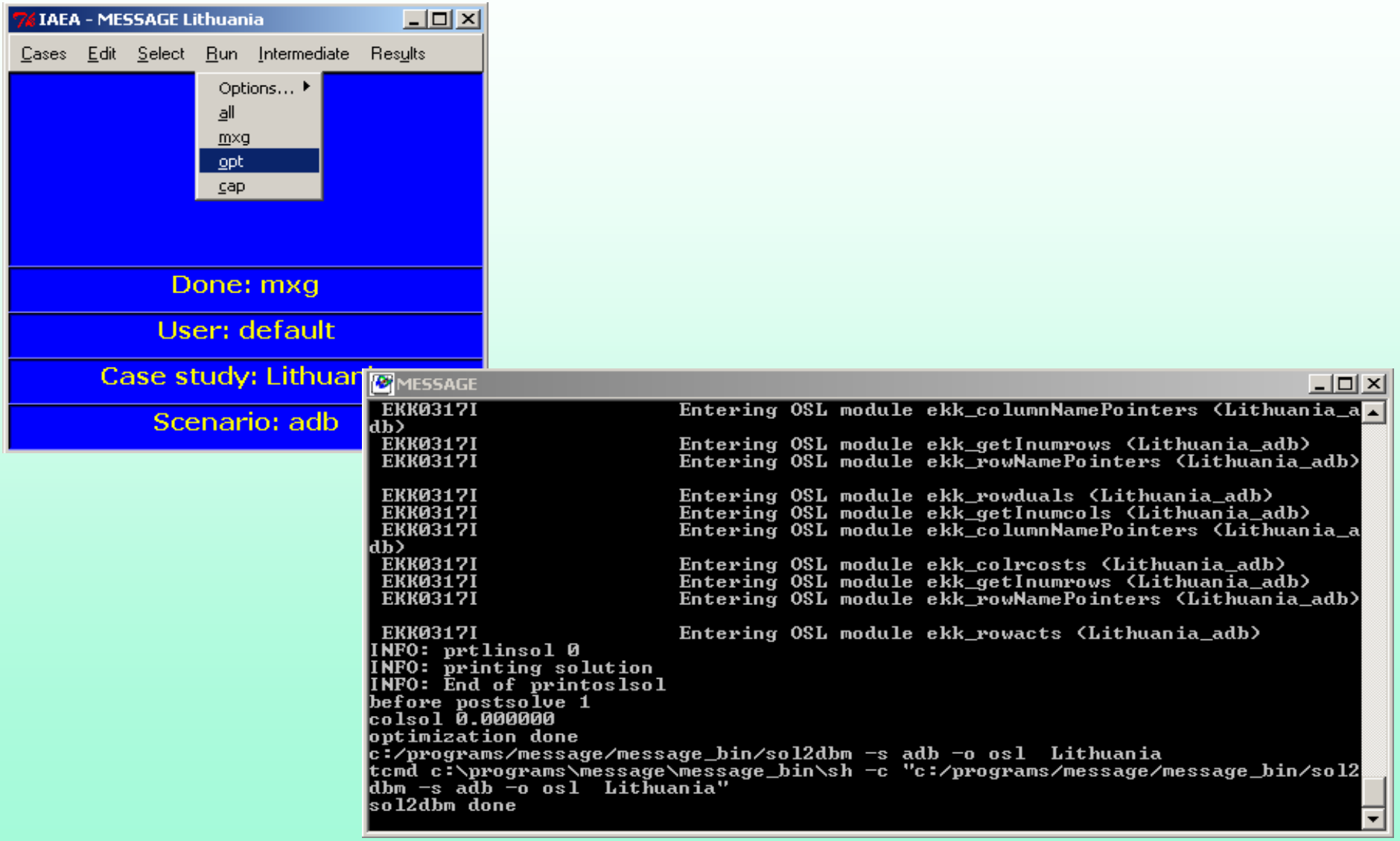
Matrix generation



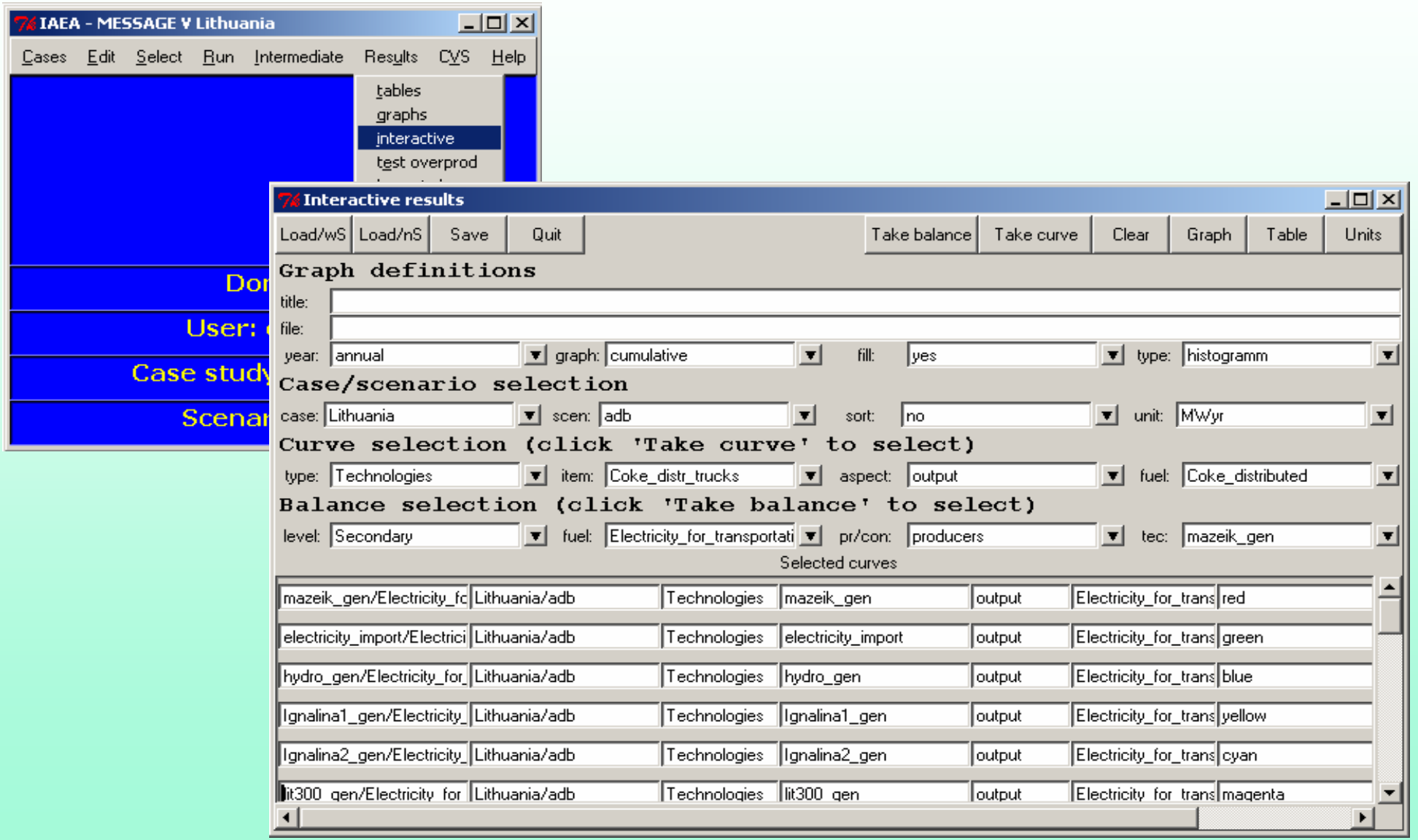




Optimization



Review of results



Review of results

- **As a result of the optimization, MESSAGE produces a time-series of all decision variables**

- **With the help of the output calculation program (CAP) or through user interface a full list of outputs can be extracted**

Review of results

- **Production and consumption of any energy form at any level and aggregation**
- **New capacity requirement for each technology/process**
- **Values of associated by products (e.g., wastes, pollutions)**
- **Total system costs, discounted to the base year**
- **O&M costs**
- **Fuel costs**
- **Investment requirement**