



the
abdus salam
international centre for theoretical physics

SMR.1524 - 1

**College on Evaluation of Energy Technologies
and Policies for Implementation of Agenda-21**

10 - 28 November 2003

Modelling of Energy System with MESSAGE

**Arvydas GALINIS
Lithuanian Energy Institute
Laboratory of Basic Energy Research
Breslaujos 3
Kaunas Lt-3035
LITHUANIA**

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

Modeling of Energy System with MESSAGE

A. Galinis

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 base (TDB and ADB)

Preparation of scenarios to be analyzed (Scenario DB)

Matrix generation

Optimization

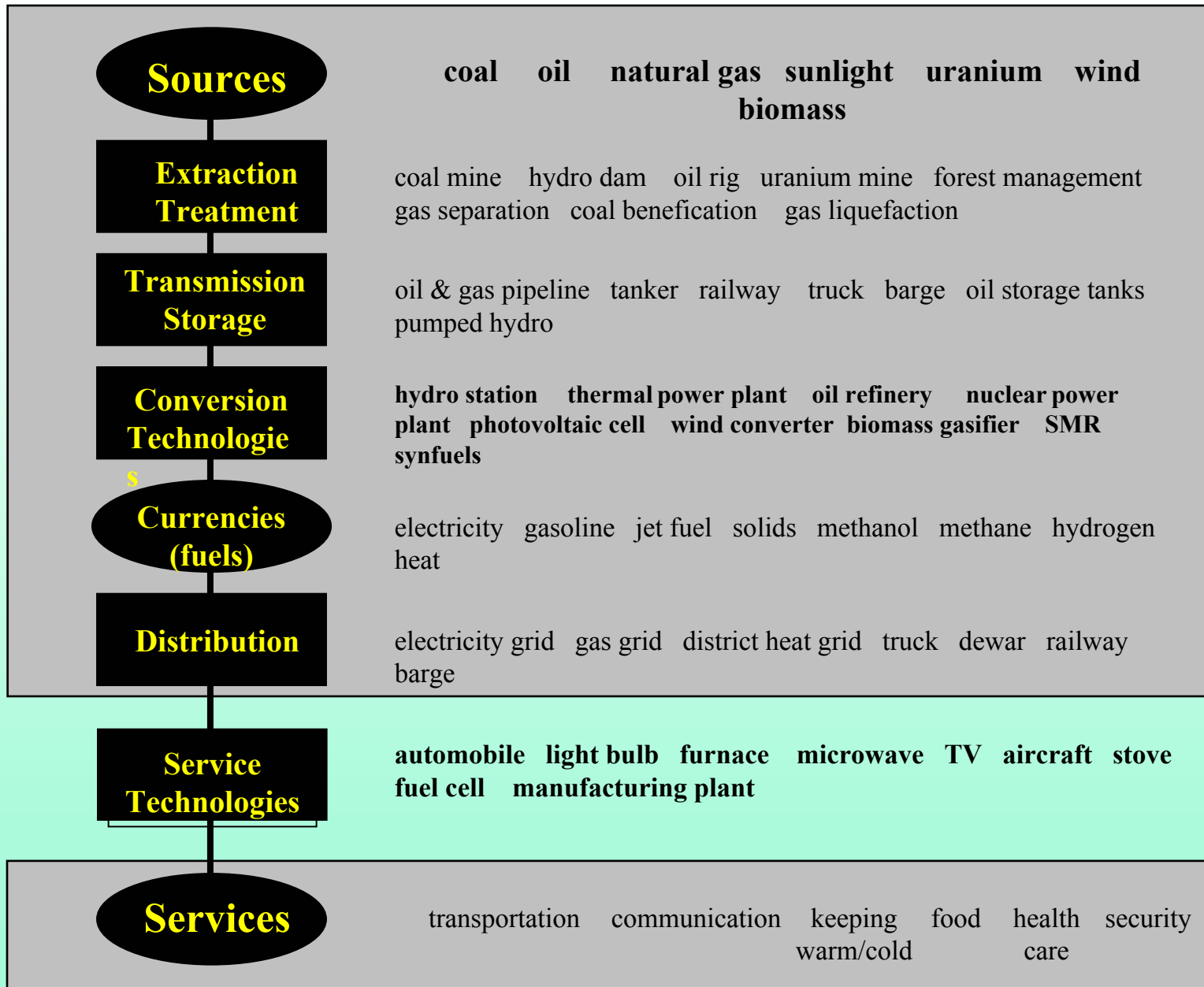
Review of results

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



What Nature Provides

Energy Sector

What People Buy

Preparation of energy flow network

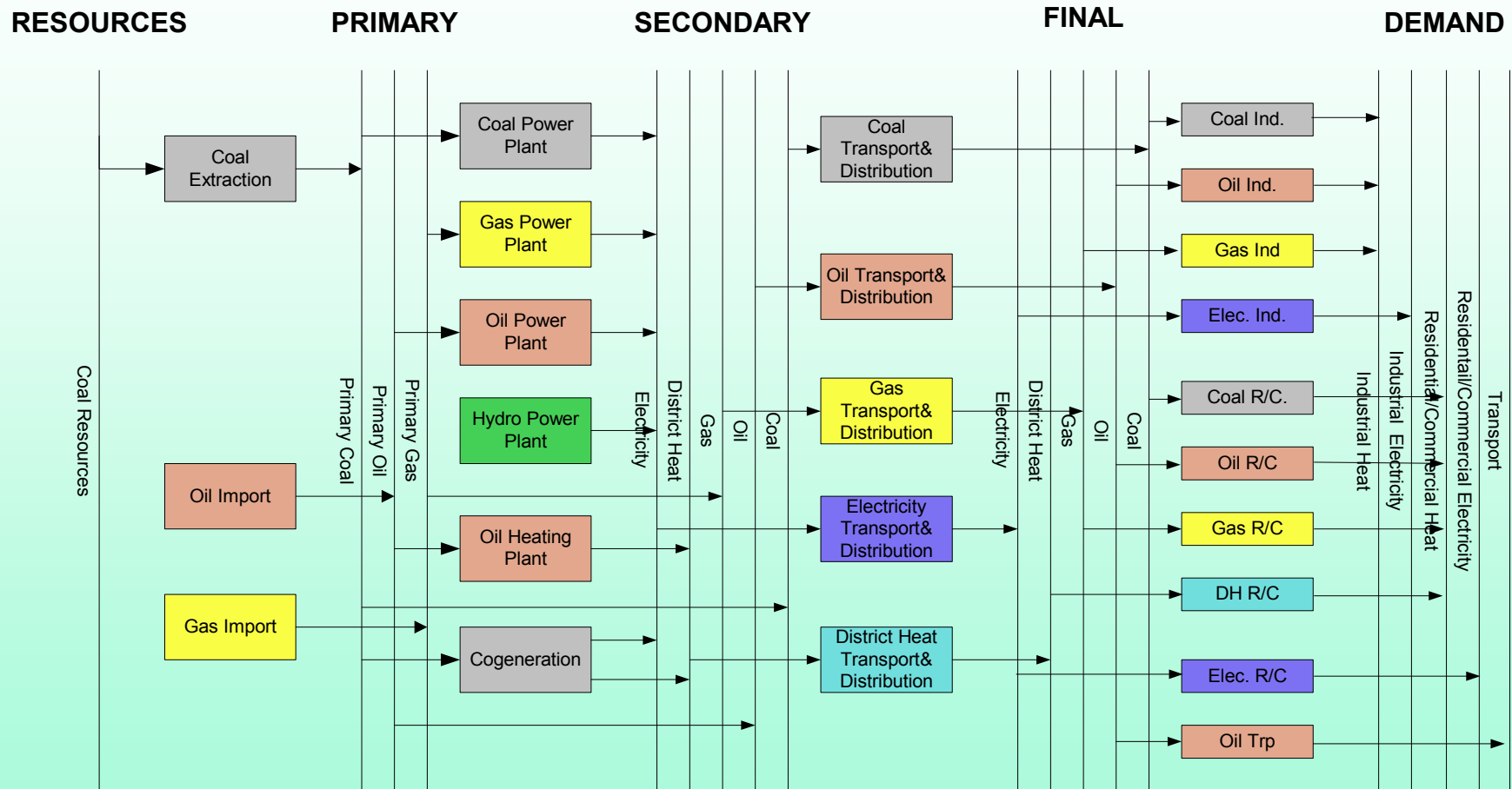
The key elements, based upon which MESSAGE builds energy system, are:

- **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 so as to allow the users to represent all kinds of technologies
- A technology can be as simple as a section of electricity transmission line or as complicated as a refinery

Preparation of energy flow network



Collection of necessary initial information

- **Technical**
- **Economic**
- **Environmental (other) and parameters used in **relations** with other technologies**
- **Parameters in MESSAGE are **dynamic**: they can **change over time** (seasonal and over year)**

Creation of model data base (TDB)

IAEA - MESSAGE glb [afr cpa eeu fsu la...]

Cases Edit Select Run Intermediate Results

- technology db
- application db
- scenario db
- update db
- cap input file
- title file
- with text editor...
- Model units
- Edit region ident
- Edit region defaults
- Notes

fault

Case study: glb

IAEA - MESSAGE glb tdb

Screen

Energyforms

Technologies

tdb

Add Del

crudeoil
coal
gas
LNG
nucfuel
biomass
fueloil
lightoil
electr
ele_int
d_heat

IAEA - MESSAGE glb tdb

Screen

Save and close screen

Energyforms

Technologies

input: all has inv: all yes no
output: all operator: and or
relations: all technologies: coal_hpl

New Del

activities

Add Ins Del Rename Reseq

alt

single entries

| Name | Unit | Value |
|------------------------|-------|--|
| main input: coal | MV/yr | 1 |
| main output: d_heat | MV/yr | 0.85 0.85 0.85 0.86 0.87 0.88 0.89 0.9 0.9 0.9 0.9 0.9 0.9 |
| var costs: \$100/kW/yr | c | 0 |

Unit Switch Time series

hist. act. Value pow. rel. Value additional options: powerchange

multiple entries

| | | | | | | |
|------|-----|-------|--------|-------|-------|-------|
| abda | bda | con1a | con2a | conca | conpa | consa |
| inp | mpa | outp | softms | | | |

description

IAEA - MESSAGE glb tdb

Screen

Energyforms

Technologies

input: all has inv: all yes no
output: all operator: and or
relations: all technologies: coal_hpl

New Del

coal_hpl

single entries

name: coal_hpl id: fixed: yes no altern. op: 1

first year: 1985 last year: initial state: on off free final state: on off free

Unit Switch Time series

| | | | | |
|--------------------------|----|----------------------------------|----------------|-------------------------|
| plant factor: share | ts | 1.4 41 42 43 44 45 46 | operation time | Unit Switch Time series |
| minutil | | | | |
| plant life: years | ts | 30 | unit size | |
| inv cost: \$100/kW | ts | 275 275 275 275 275 | constr. time | |
| fixed costs: \$100/kW/yr | ts | 29 29 29 29 29 29 29 29 29 29 29 | | |
| hist. cap. | | | | |
| min. power | | | max. power | |

multiple entries

| | | | | | | |
|-------|--------|-------|-------|-------|-------|-------|
| bdc | bdi | con1c | con2c | concc | conpc | consc |
| corin | corout | gbda | mpc | | | |

Creation of model data base (ADB)

The image shows two overlapping windows from the IAEA MESSAGE software. The background window is titled 'IAEA - MESSAGE glb [afr cpa eeu fsu la...' and has a menu open with options: technology db, application db, scenario db, update db, cap input file, title file, with text editor..., Model units, Edit region idents, Edit region defaults, and Notes. The foreground window is titled 'IAEA - MESSAGE Liet12 adb' and is in the 'Screen' mode. It features a sidebar with buttons for General, Load regions, Energyforms, Demands, Constraints, Technologies, and Resources. The main area is titled 'General data' and contains the following fields:

- country: Lithuania
- case name: Liet12
- drate: 10.0
- years: 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 20
- ntrun: 25 (dropdown), mixsw: no (dropdown), actint: 3 (dropdown), invint: 3 (dropdown)

Below these fields is a 'description' section with the following text:

Liet13
Neleidziama statyti CCGT elektrenuose
Liet12
Basic scenario. o constrains on technologies, Basic demand, Constant fuel prices, new NPP 1500 \$/kW (not forced)

A 'Chain' button is located at the bottom left of the foreground window.

Creation of model data base (ADB)

IAEA - MESSAGE Liet12 adb

Screen

General

Load regions

Energyforms

Demands

Constraints

Technologies

Resources

Chain

Energy forms

tdb adb

Ins Add Del

level name (double click to show fuels) id description

| level name | id | description |
|-----------------------|----|-------------|
| Heat | h | |
| Secondary | s | |
| Fuel_for_newPP | f | |
| Mix | m | |
| Intermediate | i | |
| Primary | p | |
| Resources_distributed | L | |
| Resources_transported | k | |

Level: Primary

Ins Add Del Save Quit

energy form id hasldr description

| energy form | id | hasldr | description |
|-------------|----|-------------------------------------|-------------|
| Gas | a | <input checked="" type="checkbox"/> | |
| HFO_HSC | b | <input type="checkbox"/> | |
| HFO_LSC | c | <input type="checkbox"/> | |
| Orimulsion | d | <input type="checkbox"/> | |
| Uranium | e | <input type="checkbox"/> | |
| Wood | f | <input type="checkbox"/> | |
| Biomass | g | <input type="checkbox"/> | |
| Peat | h | <input type="checkbox"/> | |

Creation of model data base (ADB)

IAEA - MESSAGE Liet12 adb

Screen

Technologies

General

Load regions

Energyforms

Demands

Constraints

Technologies

Resources

input: all

output: all

relations: all

name (re):

has inv all yes no

operator and or

technologies: wind_pp_gen Chain

Add from TDB New Del

Chain

Select technology

Search:

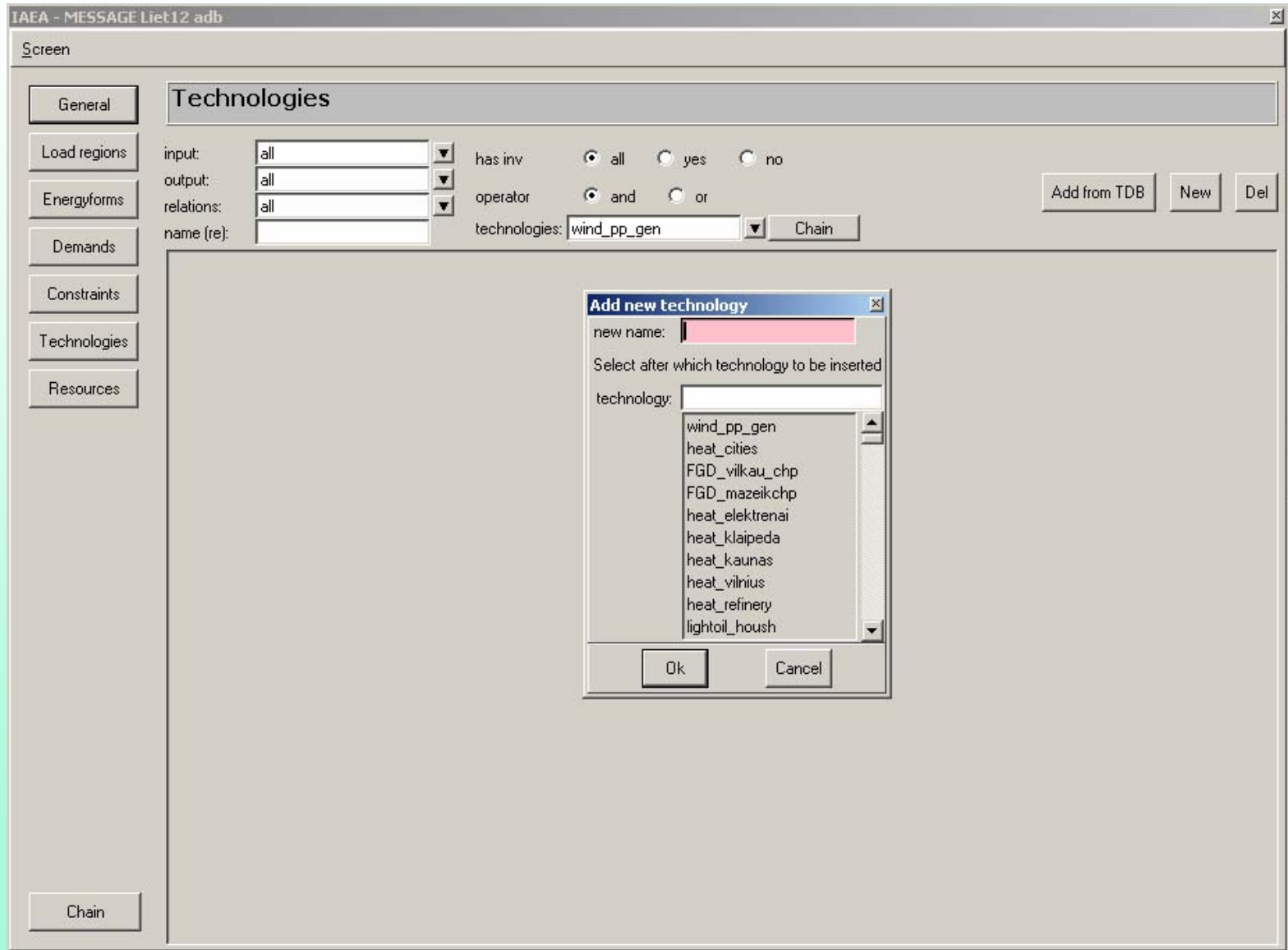
Available technologies

tec2

tech1

Quit

Creation of model data base (ADB)



Creation of model data base (ADB)

IAEA - MESSAGE Liet12 adb

Screen

General Technologies

Load regions input: all has inv all yes no

Energyforms output: all operator and or

Demands relations: all technologies: new Chain

name (re):

new

single entries

name new id a fixed yes no altern. op. 1

initial state on off free

plant factor Unit Switch Time series Unit

minutil operation time

plant life unit size

inv cost constr. time

fixed costs

hist. cap.

min. power max. power

multiple entries

| | | | | | | |
|-------|--------|-------|-------|-------|-------|-------|
| bdc | bdi | con1c | con2c | concc | conpc | consc |
| corin | corout | gbda | mpc | | | |

Chain

IAEA - MESSAGE Liet12 adb

Screen

General Technologies

Load regions input: all has inv all yes no

Energyforms output: all operator and or

Demands relations: all technologies: new Chain

activities

Add Ins Del Rename Reseq

alt a

alt a

single entries

Name Unit Value

main input loadcurves for: abs/rel

main output

Unit Switch Time series

var costs

Unit Value Switch Value

hist. act. pow. rel. additional options:

multiple entries

| | | | | | | |
|------|-----|-------|----------|-------|-------|-------|
| abda | bda | con1a | con2a | conca | conpa | consa |
| inp | mpa | outp | softlims | | | |

Chain

Creation of model data base (ADB)

IAEA - MESSAGE Liet12 adb

Screen

General Resources

Load regions select resource: Peat/Resources New Del

Energyforms

Demands

Constraints

Technologies

Resources

Peat/Resources

name Peat/Resources

| Unit | Switch | Time series |
|-------|-------------------------------------|---|
| fcost | <input type="checkbox"/> | |
| uplim | <input checked="" type="checkbox"/> | 22 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 35 35 35 35 40 40 40 40 40 40 40 40 |

grades

Add Ins Del Rename

grade a

grade a

single entries

| Unit | Value | Unit | Value | Unit | Value |
|--------|-------|---------|-------|-------|-------|
| volume | | initval | | byrex | |

| Unit | Switch | Time series |
|--------|-------------------------------------|-------------|
| resrem | <input type="checkbox"/> | |
| cost | <input checked="" type="checkbox"/> | 0.01 |
| uplim | <input type="checkbox"/> | |

multiple entries

bda con1a con2a conca conpa mpa

description

Chain

Creation of model data base (ADB)

IAEA - MESSAGE Liet12 adb

Screen

General
Load regions
Energyforms
Demands
Constraints
Technologies
Resources

Demands

Add Delete Import load curves: abs/rel Import

| energy form/level | unit | switch | data (double click to edit) | Comment | Import |
|-----------------------------|-------|--------|---|---------|--------|
| Electricity_total/Useful | MW/yr | ts | 707.4 743.6 779.8 816.0 852.2 888.3 926.6 964.9 1003.1 1041.4 1079.7 1111.0 1 | | |
| Mazeikiai_refinery_electric | MW/yr | c | 4.2 | | |
| Industry/Useful | MW/yr | ts | 1466.68 1531.93 1597.19 1662.45 1727.71 1792.97 1823.74 1854.51 1885.28 19 | | |
| City_heat/Useful | MW/yr | ts | 439 448 458 468 478 488 499 511 522 534 546 554 562 570 578 586 593 601 60 | | |
| Households/Useful | MW/yr | ts | 946.23 976.79 1007.35 1037.92 1068.48 1099.04 1105.67 1112.30 1118.93 1125 | | |
| Transport/Useful | MW/yr | ts | 1387.41 1439.77 1492.12 1544.48 1596.83 1649.19 1703.02 1756.86 1810.69 18 | | |
| Elektrenai_heat/Useful | MW/yr | ts | 18 18 18 19 19 19 19 20 20 20 21 21 21 22 22 22 23 23 23 24 24 | | |

Chain

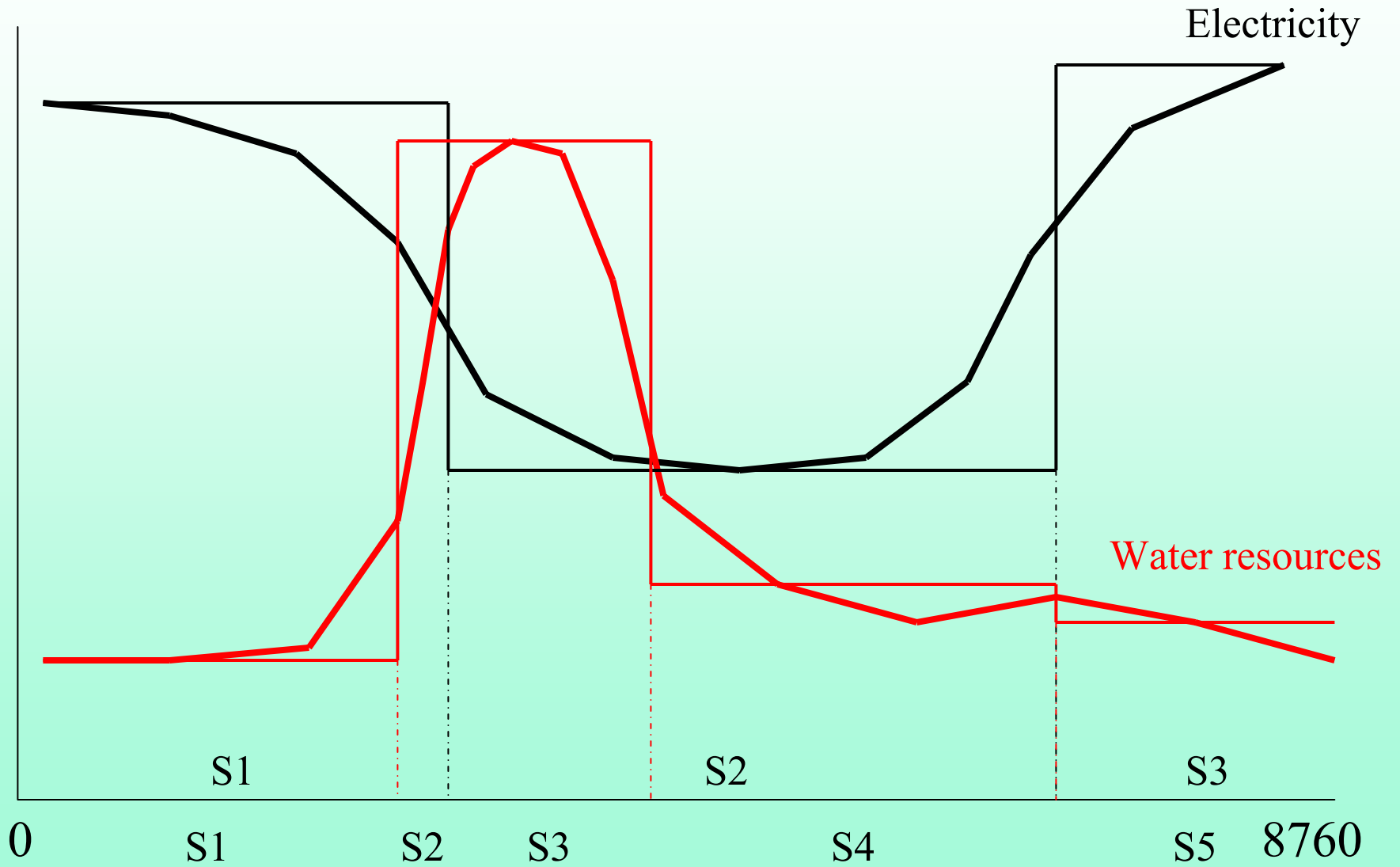
Definition of load regions

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

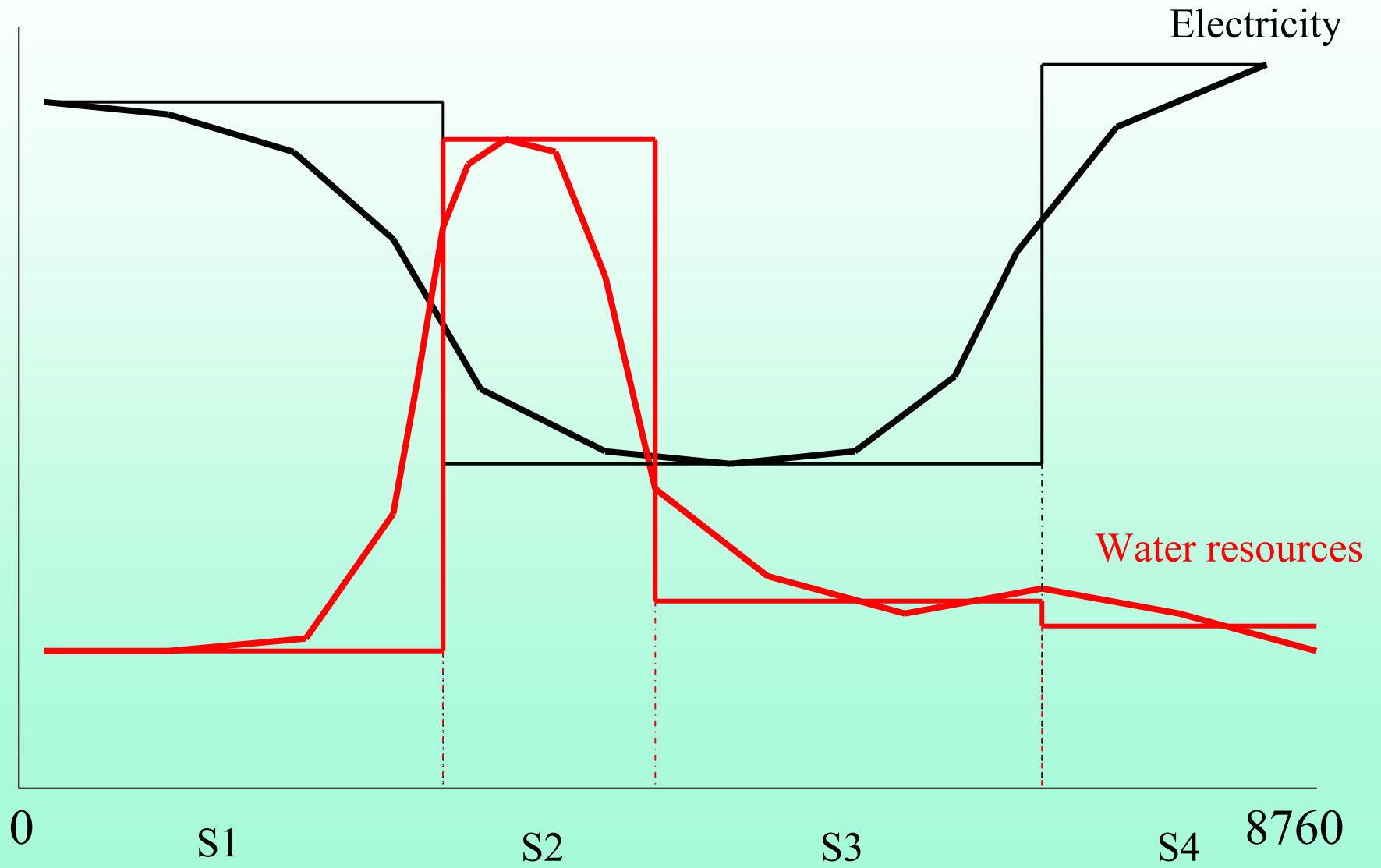
Definition of load regions

- 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

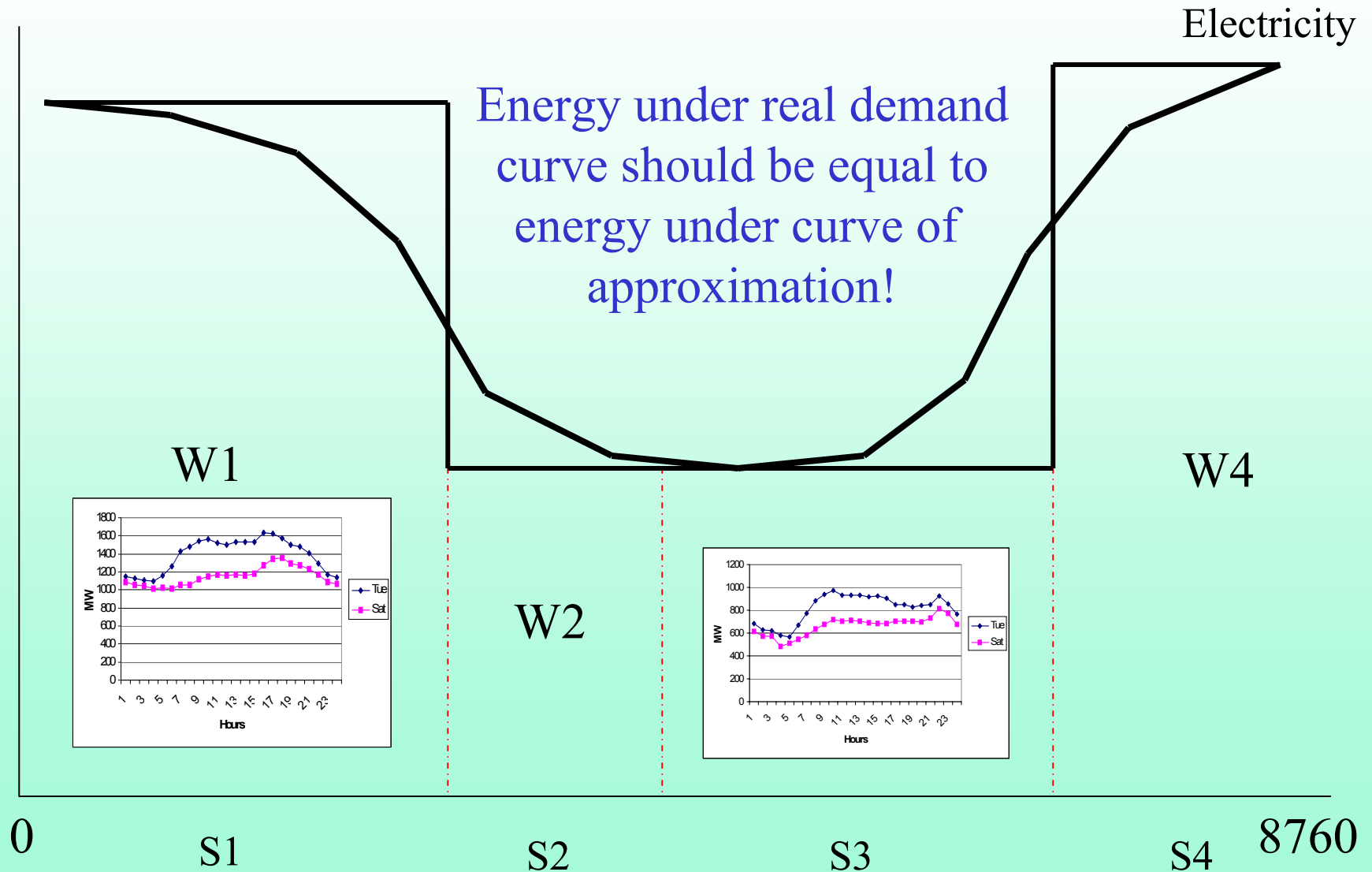
Definition of load regions (Dividing into seasons)



Definition of load regions (Reduction of seasons)

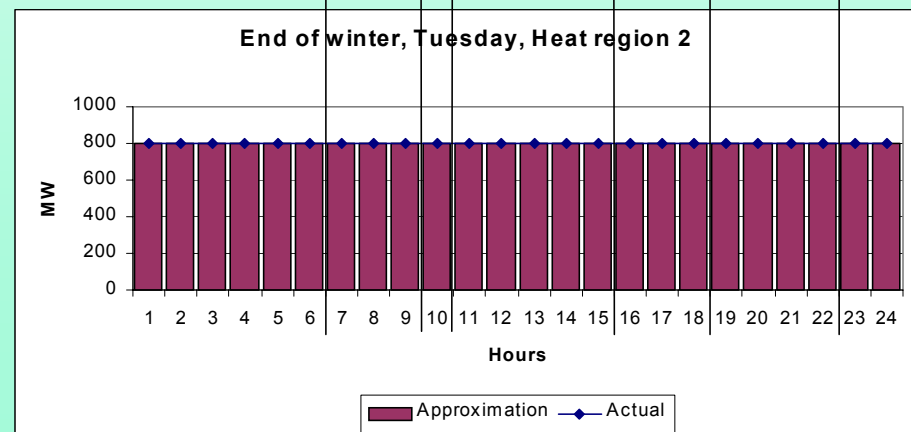
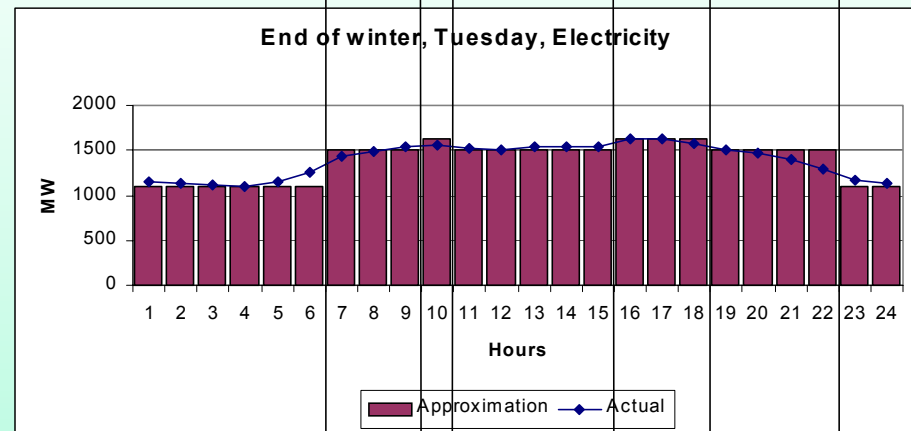
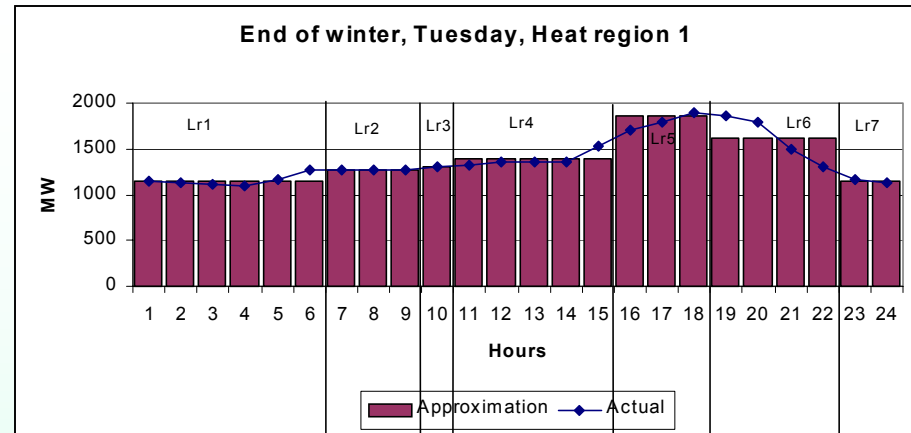


Definition of load regions (Final representation of demand)



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

IAEA - MESSAGE Liet12 adb

Screen

Load region definition

Country: Lithuania Holiday tables Day types

Type: seasonal Year: 2000 No. of seasons: 3

| Name | Start date | days | parts |
|---------|------------|------|-------|
| Winter1 | 2000-01-01 | 2 | 7 5 |
| Summer | 2000-04-07 | 2 | 4 5 |
| Winter2 | 2000-11-01 | 2 | 7 4 |

Ok Reload Clear Delete year Delete season

MESSAGE - Day type definitions

Add Del Save Quit

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday | Holiday |
|-----------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Monday | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Tuesday | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Wednesday | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Thursday | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Friday | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Saturday | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sunday | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| Workday | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| SunandHol | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| SSH | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| anyday | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Chain

Definition of load regions (Creation of application data base) Definition of holidays

IAEA - MESSAGE Liet12 adb

Screen

Load region definition

Country: Lithuania

Type: seasonal

| Name | Start date | days | parts |
|---------|------------|------|-------|
| Winter1 | 2000-01-01 | 2 | 7 5 |
| Summer | 2000-04-07 | 2 | 4 5 |
| Winter2 | 2000-11-01 | 2 | 7 4 |

Holiday table

prev 2000 next

| Jan | Feb | Mar | Apr | Mai | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Mo | Tu | We | Th | Fr | Sa | Su | | | | | |
| | | | | | 1 | 2 | | | | | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | | | |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | | | | | |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | | | | | |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 | | | | | |
| 31 | | | | | | | | | | | |

Chain

Definition of load regions (Creation of application data base) Parameters of load regions

IAEA - MESSAGE Liet12 adb

Screen

General

Load regions

Energyforms

Demands

Constraints

Technologies

Resources

Chain

Load region definition

Country: Lithuania Holiday tables Day types

Type: seasonal Year: 2000 No. of seasons: 3

| Name | Start date | days | parts |
|---------|------------|------|-------|
| Winter1 | 2000-01-01 | 2 | 7 5 |
| Summer | 2000-04-07 | 2 | 4 5 |
| Winter2 | 2000-11-01 | 2 | 7 4 |

Winter1 Summer Winter2

Workday SSH

| name | length | name | length |
|-------|--------|-------|--------|
| lr1 | 0.25 | lr1 | 0.2917 |
| lr2 | 0.125 | lr2 | 0.3333 |
| lr3 | 0.0417 | lr3 | 0.2083 |
| lr4 | 0.2083 | lr4 | 0.125 |
| lr5 | 0.125 | lr5 | 0.0417 |
| lr6 | 0.1667 | Total | 1.0 |
| lr7 | 0.0833 | | |
| Total | 1.0 | | |

OK Reload Clear Delete year Delete season

Definition of load regions (Creation of application data base)

IAEA - MESSAGE Liet 12 adb

Screen

Demands

Add Delete Import load curves: Electricity_total/Useful abs/rel Import

| energy form/level | unit | switch | data (double click to edit) | Comment | Import |
|-----------------------------|------|--------|---|---------|--------|
| Electricity_total/Useful | MWyr | ts | 707.4 743.6 779.8 816.0 852.2 888.3 926.6 964.9 1003.1 1041.4 1079.7 1111.0 1 | | |
| Mazeikiai_refinery_electric | MWyr | c | 4.2 | | |
| Industry/Useful | MWyr | ts | 14 | | |
| City_heat/Useful | MWyr | ts | 43 | | |
| Households/Useful | MWyr | ts | 94 | | |
| Transport/Useful | MWyr | ts | 13 | | |
| Elektrenai_heat/Useful | MWyr | ts | 18 | | |

Load curve for: Electricity_total/Useful

Add year Delete year Graph Save

2000

| Winter1 | Summer | Winter2 |
|----------|----------|----------|
| 0.356189 | 0.446689 | 0.197122 |

Winter1 Summer Winter2

| Workday | SSH |
|------------|------------|
| 0.739649 | 0.260351 |
| lr1 0.1979 | lr1 0.2572 |
| lr2 0.135 | lr2 0.335 |
| lr3 0.049 | lr3 0.2456 |
| lr4 0.225 | lr4 0.1256 |
| lr5 0.1471 | lr5 0.0366 |
| lr6 0.18 | |
| lr7 0.066 | |

IAEA - MESSAGE Liet 12

2000 Save Quit

2000 Winter1 35.6188999 Summer 44.6689000 Winter2 19.7121999

Electricity_total/Useful 2000

Legend:

- curve
- year_start
- Winter1Workday
- Winter1
- SummerWorkday
- Summer
- Winter2Workday
- Winter2

ymin 324.87792519 ymax 1279.67172083 x y

all y graph type: step

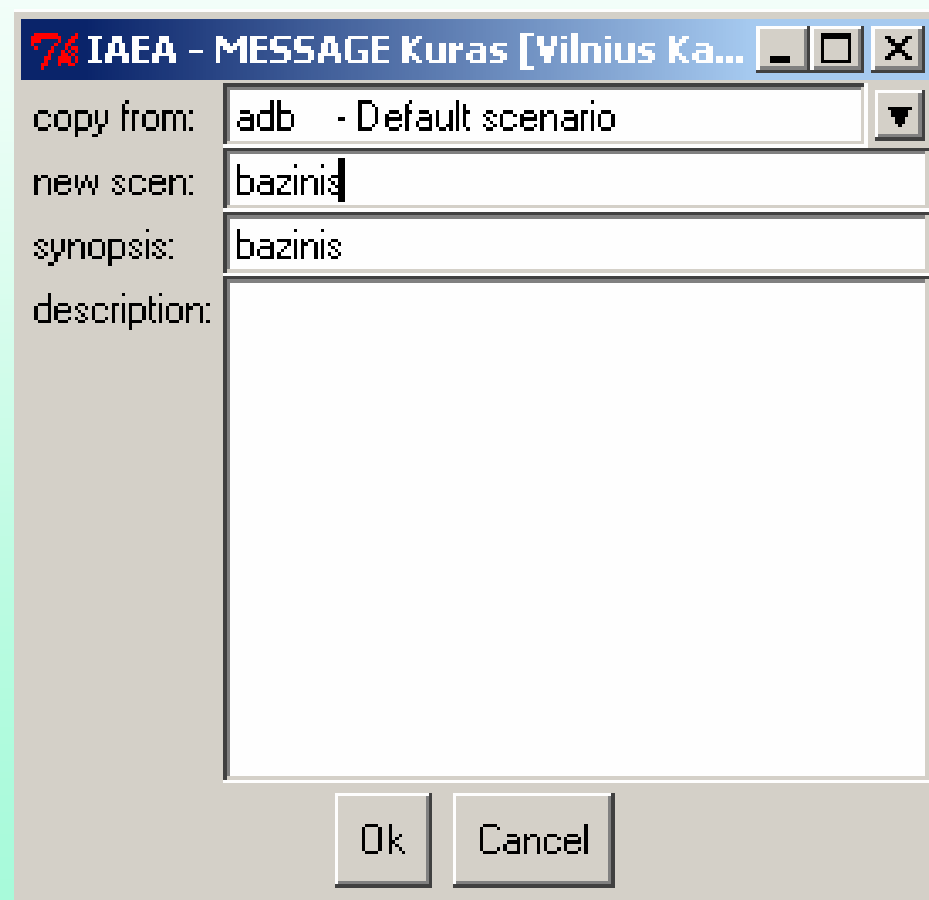
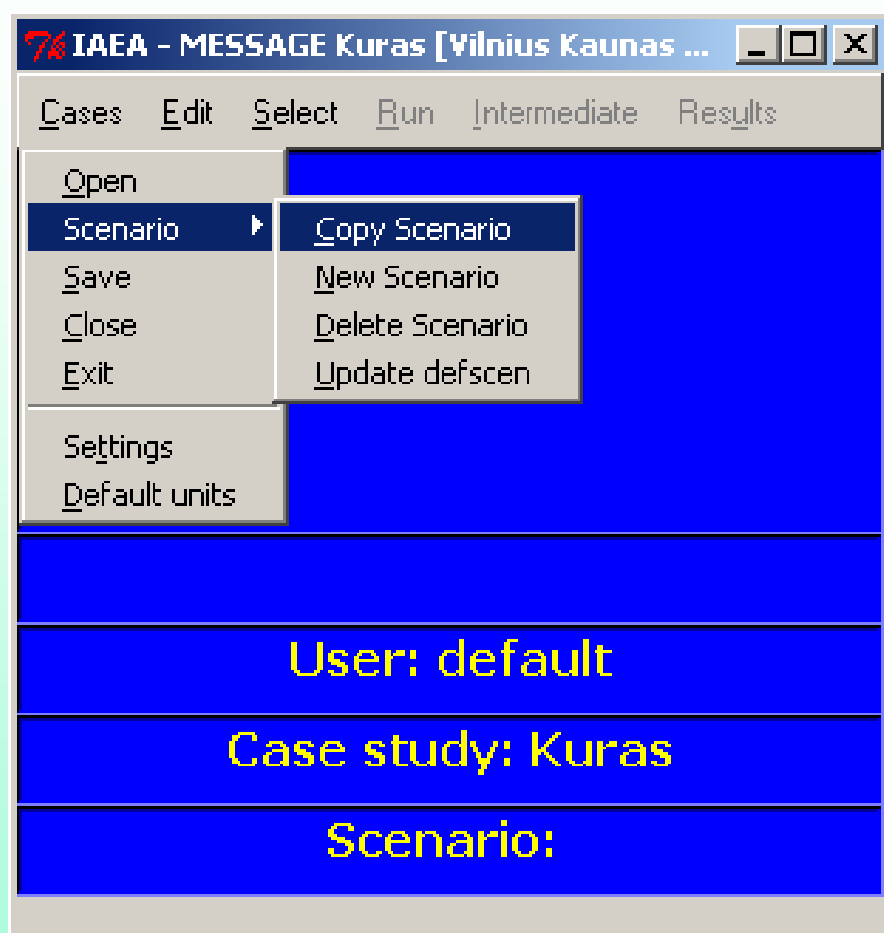
ymin=0 ymin=min ymax=max

Chain

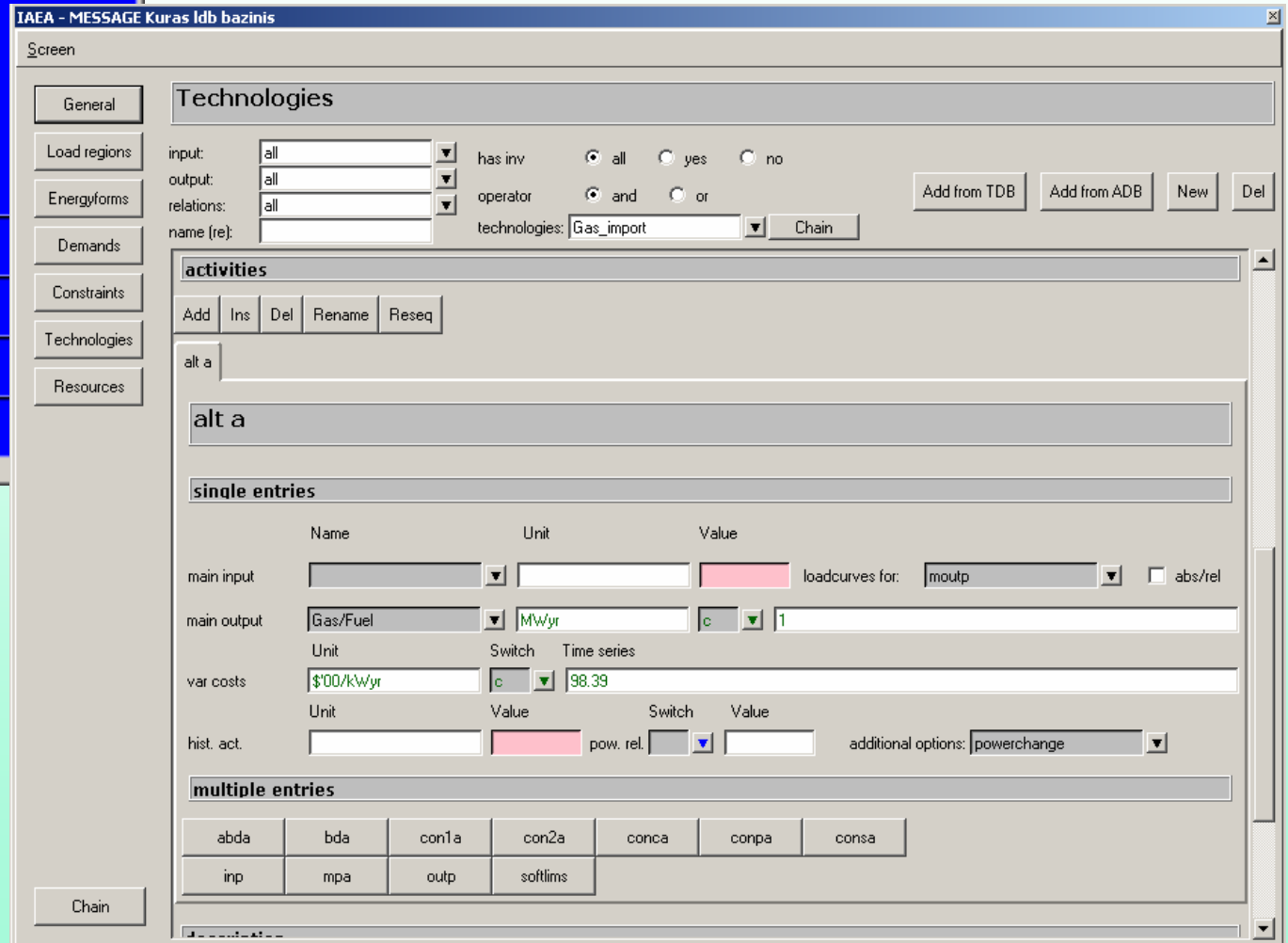
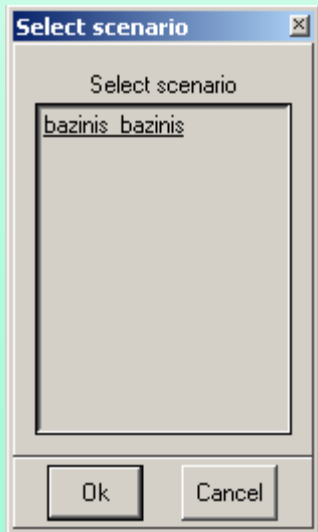
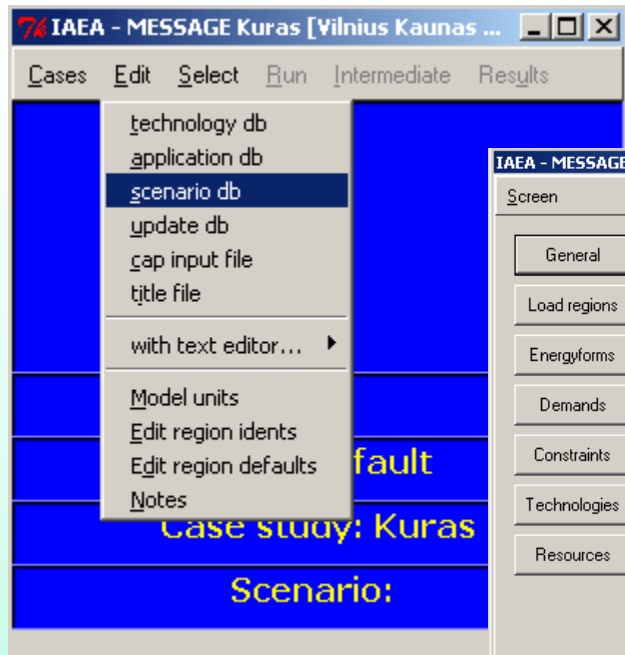
IAEA - MESSAGE Liet 12

2000 Save Quit

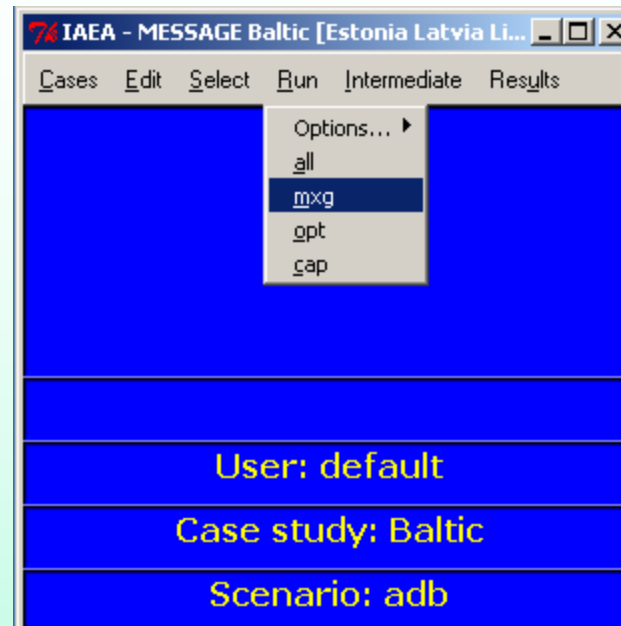
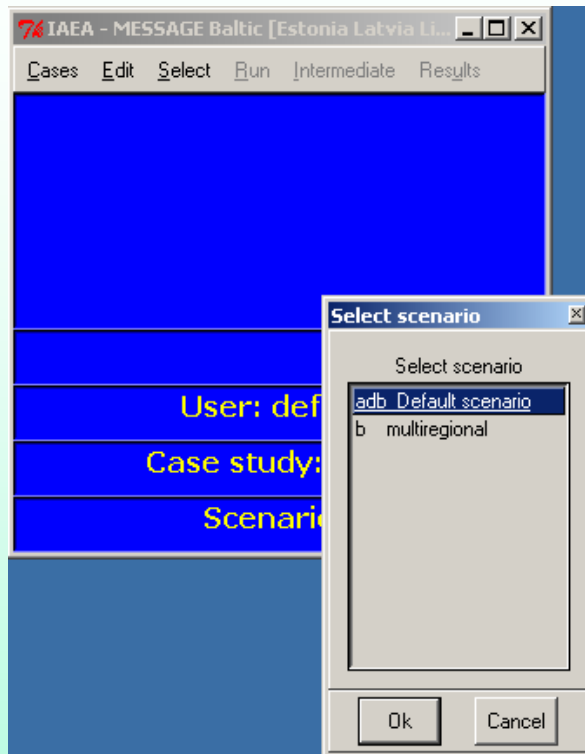
Preparation of scenarios to be analyzed (Scenario DB)



Preparation of scenarios to be analyzed (Scenario DB)

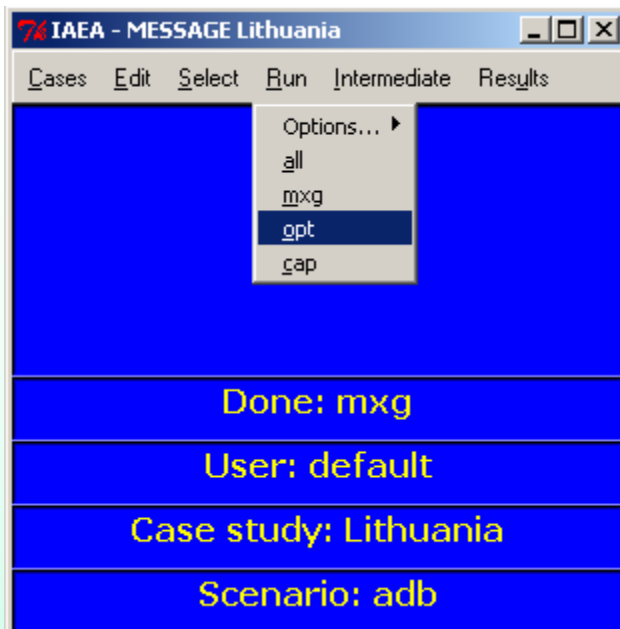


Matrix generation



```
MESSAGE
Baltic
c:/programs/message/message_bin/mxg -f mxgerr -o osl -v -n no -s adb Baltic
tcmd c:\programs\message\message_bin\sh -c "c:/programs/message/message_bin/mxg
-f mxgerr -o osl -v -n no -s adb Baltic"
c:/programs/message/models/BalticStudy/Baltic
Generating region Baltic
Generating region Estonia
Generating region Latvia
Generating region Lithuania
Preparing matrix
Writing matrix
rows: 641
cols: 2718
elms: 2718
rhs: 224
rngs: 0
bnds: 4
time for sorting rows: 0 sec
time for sorting columns: 0 sec
time for writing columns: 0 sec
time for writing rhs: 0 sec
time for writing ranges: 0 sec
time for writing bounds: 0 sec
Matrixgenerator done
mxg done
```

Optimization



```
MESSAGE
EKK0317I      Entering OSL module ekk_columnNamePointers <Lithuania_a
db>
EKK0317I      Entering OSL module ekk_getInumrows <Lithuania_adb>
EKK0317I      Entering OSL module ekk_rowNamePointers <Lithuania_adb>

EKK0317I      Entering OSL module ekk_rowduals <Lithuania_adb>
EKK0317I      Entering OSL module ekk_getInumcols <Lithuania_adb>
EKK0317I      Entering OSL module ekk_columnNamePointers <Lithuania_a
db>
EKK0317I      Entering OSL module ekk_colrcosts <Lithuania_adb>
EKK0317I      Entering OSL module ekk_getInumrows <Lithuania_adb>
EKK0317I      Entering OSL module ekk_rowNamePointers <Lithuania_adb>

EKK0317I      Entering OSL module ekk_rowacts <Lithuania_adb>
INFO: prtlnsol 0
INFO: printing solution
INFO: End of printoslsol
before postsolve 1
colsol 0.000000
optimization done
c:/programs/message/message_bin/sol2dbm -s adb -o osl Lithuania
tcmd c:\programs\message\message_bin\sh -c "c:/programs/message/message_bin/sol2
dbm -s adb -o osl Lithuania"
sol2dbm done
```


Review of results

- **As a result of the optimization, MESSAGE produces a time-series values of **all decision variables****
- **For **each technology**:**
 - Activity values
 - Capacity values
- **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**