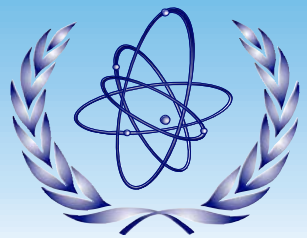


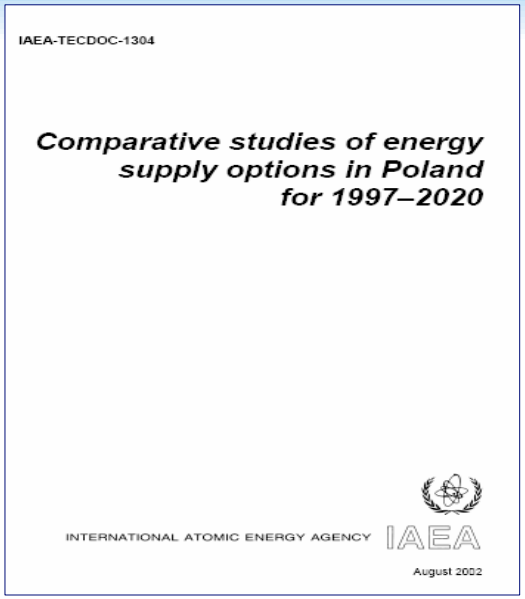
International Atomic Energy Agency

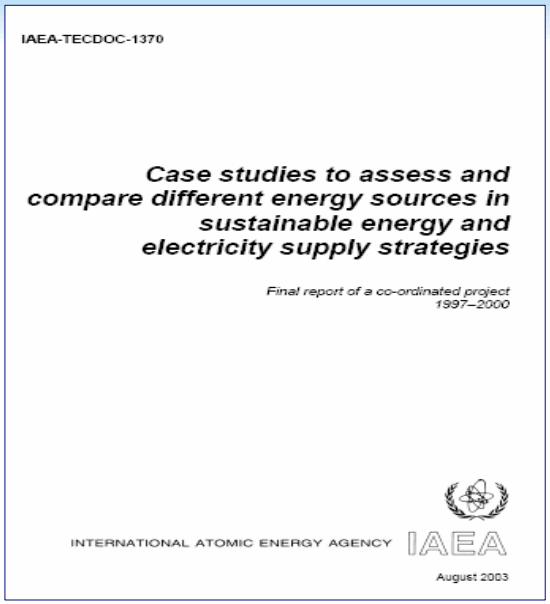
Energy Modeling in INPRO DESAE Integrated model

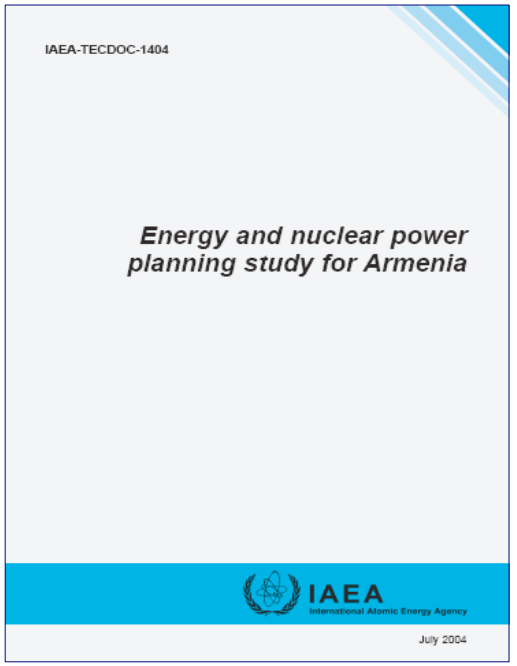
Mikhail Khoroshev, IAEA

Workshop on Modelling and Quality Control for Advanced and Innovative Fuel Technologies

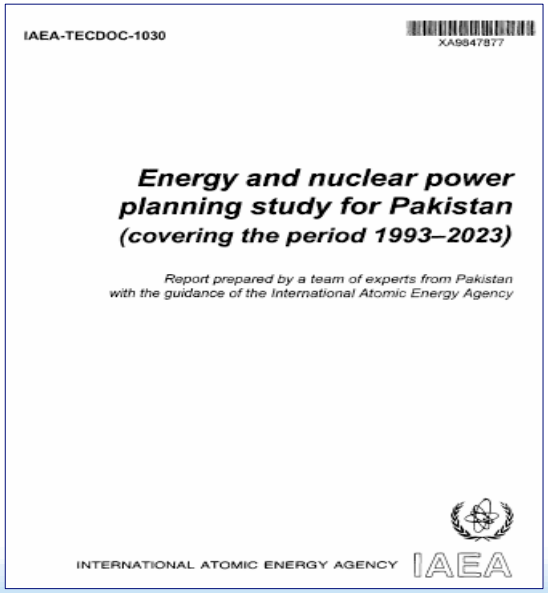
International Centre for Theoretical Physics, ICTP, Triest, Italy, 14-25 November 2005

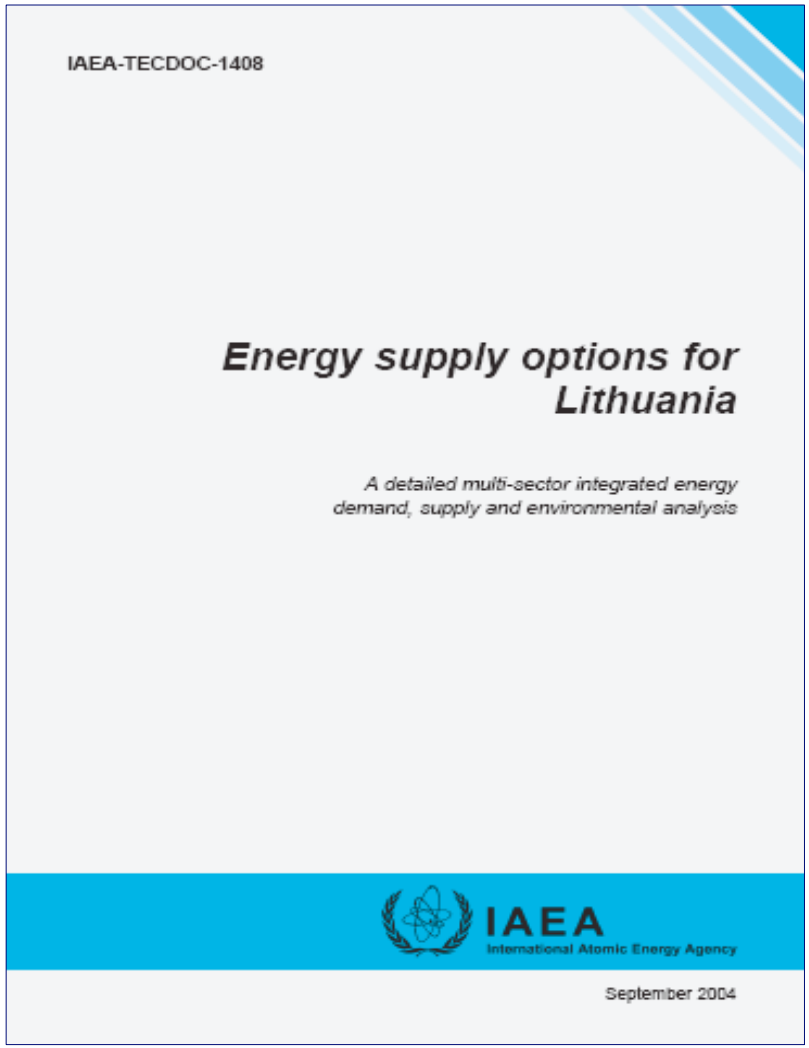

IAEA-TECDOC-1304
Comparative studies of energy supply options in Poland for 1997–2020
INTERNATIONAL ATOMIC ENERGY AGENCY
IAEA
August 2002


IAEA-TECDOC-1370
Case studies to assess and compare different energy sources in sustainable energy and electricity supply strategies
Final report of a co-ordinated project 1997–2000
INTERNATIONAL ATOMIC ENERGY AGENCY
IAEA
August 2003


IAEA-TECDOC-1404
Energy and nuclear power planning study for Armenia
IAEA
International Atomic Energy Agency
July 2004


IAEA-TECDOC-1259
Nuclear power programme planning: An integrated approach
INTERNATIONAL ATOMIC ENERGY AGENCY
IAEA
December 2001


IAEA-TECDOC-1030
XA9847877
Energy and nuclear power planning study for Pakistan
(covering the period 1993–2023)
Report prepared by a team of experts from Pakistan with the guidance of the International Atomic Energy Agency
INTERNATIONAL ATOMIC ENERGY AGENCY
IAEA


IAEA-TECDOC-1408
Energy supply options for Lithuania
A detailed multi-sector integrated energy demand, supply and environmental analysis
IAEA
International Atomic Energy Agency
September 2004


IAEA-TECDOC-1469
Comparative assessment of energy options and strategies in Mexico until 2025
Final report of a coordinated research project 2000–2004
IAEA
International Atomic Energy Agency
October 2006

General objective of *INPRO* task 4

Analyse O**pportunities and Challenges for Large-scale Global NE** to define responses that have to be done today in institutional and technology development areas:

- to facilitate global NE use in medium term and
- to prepare basis for NE to play an important role for global sustainable development.

Tools for Modelling

- Codes to be used for modelling energy scenarios and structuring of INS
  - MESSAGE: Model of energy supply systems and their general environmental impact
  - MAED: model for analysis of energy demand
  - WASP: Wien automatic system planning package
  - ENEP: Energy and power evaluation system
  - FINPLAN: Model for financial analysis of electric sector expansion plans
  - SIMPACTS: simplified approach for estimating impacts of electricity generation
  - DESAE: Dynamic Energy System, Simulation of INS
  - SYRTEX: Competitiveness of INS

Modelling Needs
for
Joint Study on Assessment of INS based on Closed Nuclear Fuel Cycle with Fast Reactors using INPRO Methodology

IAEA-TECDOC-1434

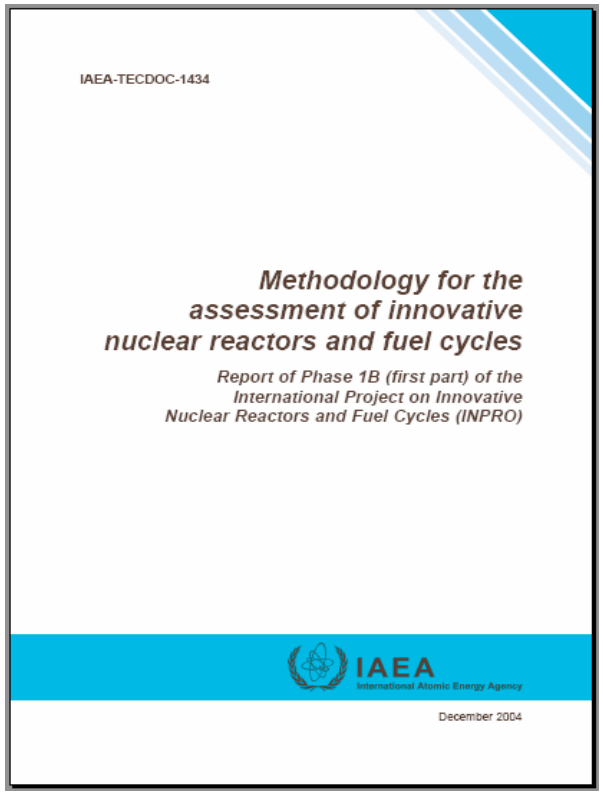
CHAPTER 3 – Method for Assessment

* **Screening assessment**
- **definition of Acceptance Limits**
- **evaluation of Indicators**

* **Comparative assessment**
- **procedure for aggregating judgments on Criteria**

* **RD&D assessment**
- **identification of priorities for R&D**

***Question:* Where do we need modelling?**
***Answer:* At every stage of the Assessment.**



Tools for Modelling

- Codes to be used for modelling energy scenarios and optimizing INS
  - MESSAGE: Model of energy supply systems and their general environmental impact
  - MAED: model for analysis of energy demand
  - WASP: Wien automatic system planning package
  - ENEP: Energy and power evaluation system
  - FINPLAN: Model for financial analysis of electric sector expansion plans
  - SIMPACTS: simplified approach for estimating impacts of electricity generation
  - DESAE: Dynamic Energy System, Simulation of INS
  - SYRTEX: Competitiveness of INS

DESAE interactive model

The interactive model for quantitative assessment of nuclear energy system key indicators.

(Dynamic of Energy System – Atomic Energy created by unk groups)

Tsibulskiy V.F., Davidenko V.D., Subbotin S.A.
unk@dhtp.kiae.ru

DESAE CODE

- **The DESAE (Dynamic of Energy System) is an interactive model computer code for the quantitative assessment of nuclear energy systems of various countries pursuing nuclear energy program around the world.**
- **This code is based on MATLAB computing with graphical user interface facility.**

UTILITIES OF THE DESAE CODE

- The user can select a country of interest from the world map that is built in the code.
- Choose reactors from the database (7-types available) in the code. There is also an option for choosing the recycling plants (4- types available).
- The database of each reactor type can be edited as per one's own option for further calculations.
- It is possible to use the code for analyzing the national, regional and global scenarios

OUTPUTS OF DESAE

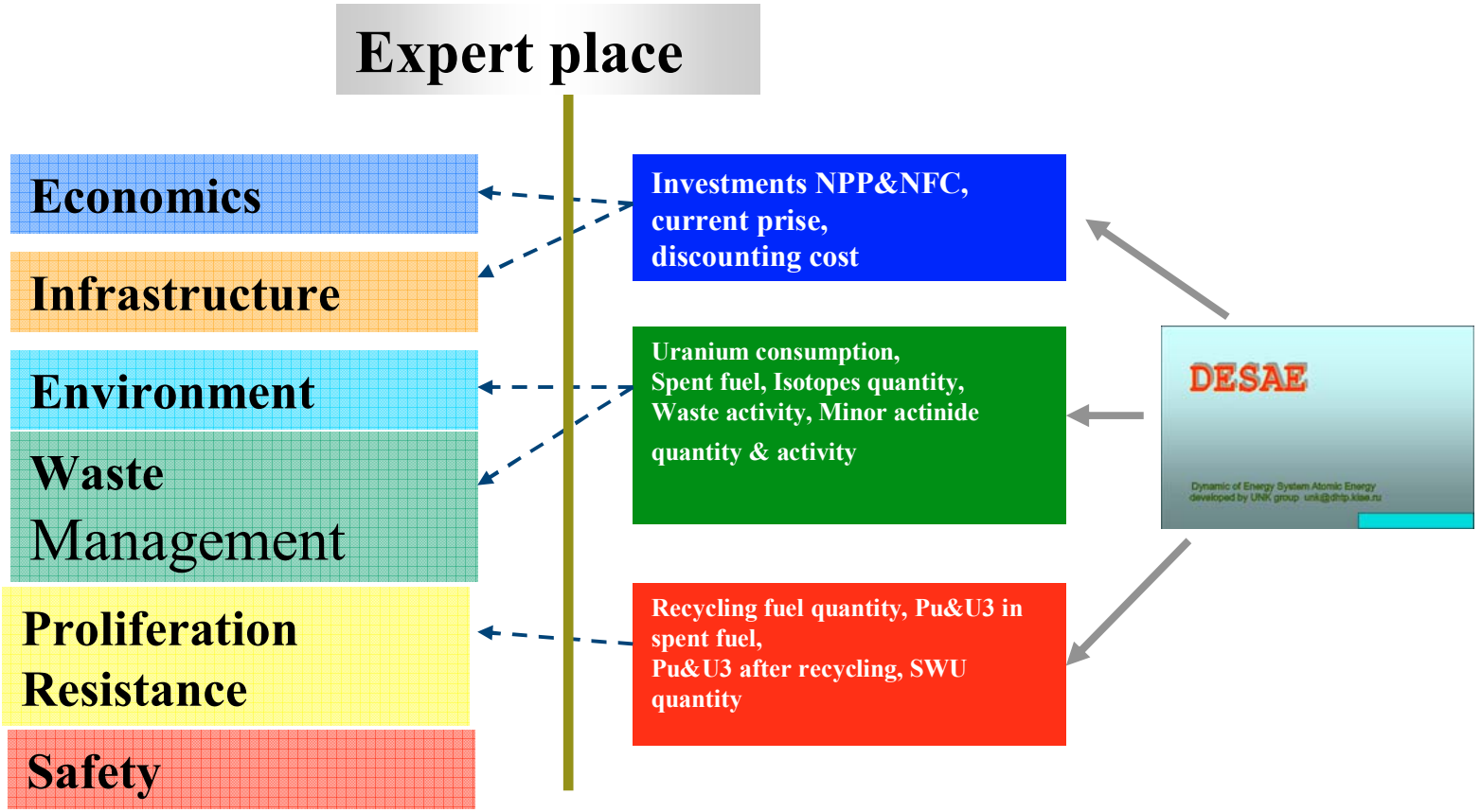
- **With all these input parameters set, the code can be executed to compute 28 output parameters which are very useful for the dynamic and economic assessment of a country's nuclear energy scenario.**
- **The output results encompass estimation of the total nuclear power generated during a specified time span to economic specific values.**
- **There are options to obtain these outputs either in the form of charts or in the form of tables.**

BARC evaluation, India: DESAE Code has very good potential for use in the context of INPRO

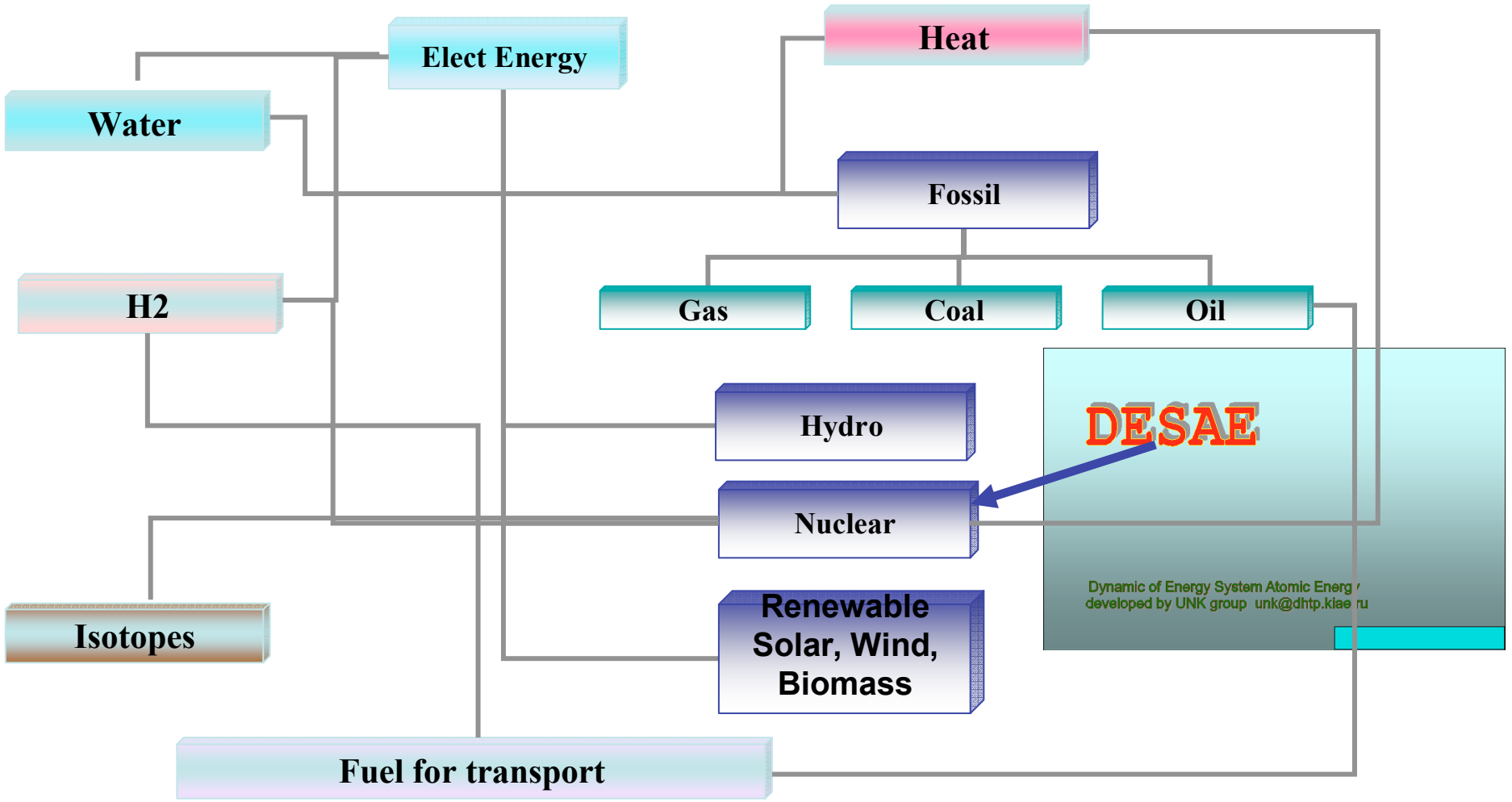
DESAE is an excellent code to plan and optimize country's nuclear power programme by studying possible combinations of different types of reactors

- Estimation of nuclear fuel resources and their optimization
- Estimation of infrastructure needed for various aspects of fuel cycle
- Estimation of overall economics
  - Investments required in nuclear plant building, in fuel recycling, in fuel fabrication etc.
- Estimation of amount of important material needed
- Graphical user interface makes execution of the code very easy
- At a glance one can compare nuclear scenario of different countries

DESAE code in INPRO methodology



DESAE in Energy System



The main tasks

DESAE

1) Calculations of material and economic resources for development of NE.

2) Comparison of various reactor types.

3) Studies of various options of closed fuel cycle.

4) Comparison of structure of NE for various regions.

5) Definition of reactor characteristics most important for the system (INS).

6) Definition of various factors of sensitivity (prices, time delay …).

7) Information support for the analysis of current conditions in NE

INS scenario analysis tool

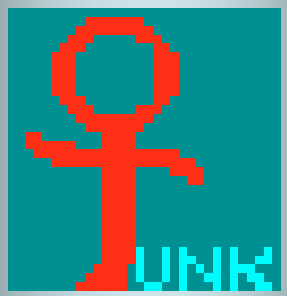
INPUT DATA

Reactor Types

Reactor Power
(as a function of time)

Costs of:
Fuel;
Operating & Maintenance
Capital,
etc.

DESAE



MAIN OUTPUT DATA

Natural parameters:
- **Energy production;**
- **Consumption of natural Uranium;**
- **Spent Fuel;**
- **Quantity of Fissile Isotopes;**
- **Quantity of Recycled Isotopes;**
- **Quantity of Minor actinides;**
- **Activity of Spent Fuel;**
- **Quantity of Critical materials;**
- **Quantity of dangerous materials.**

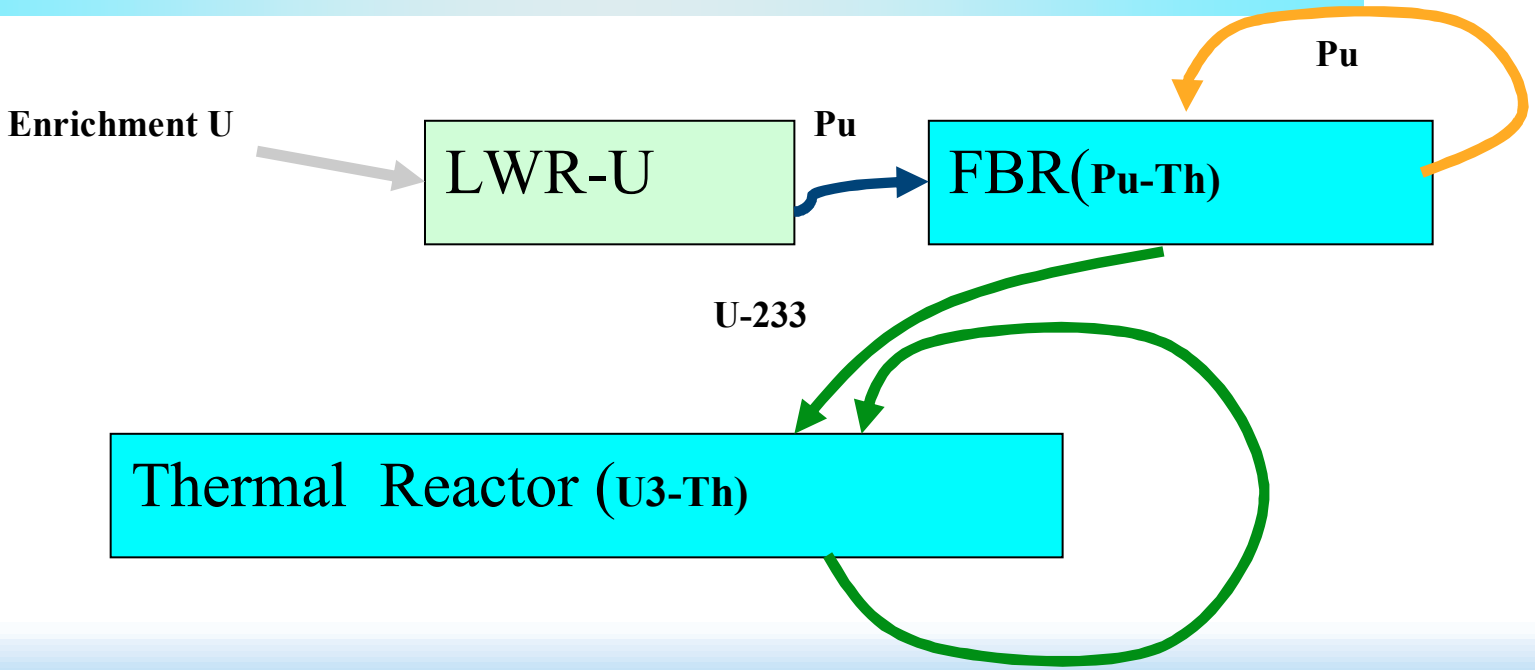
Economics:
- **Required Investments;**
- **Current price of energy;**
- **Net present value of Investment.**

Example

DESAE

Task:

U-Pu-Th closed fuel cycle for World AE.
Scenarios B2:
B2 ={2050 year-2000GW; 2100year -5000GW};



Reactor data, the main difference DESAE &DESAE-2

DESAE

Efficiency (electricity)

Fuel loading, t/GWe

Burnup, GWdays/t

Isotopes

- U-233
- U-235
- U-236
- Pu-238
- Pu-239
- Pu-240
- Pu-241
- Pu-242
- Am-241
- Cm-244

DESAE-2

Reactor power, GW
Efficiency (electricity)
Efficiency (high temperature)
Efficiency (low temperature)
Efficiency (water production)

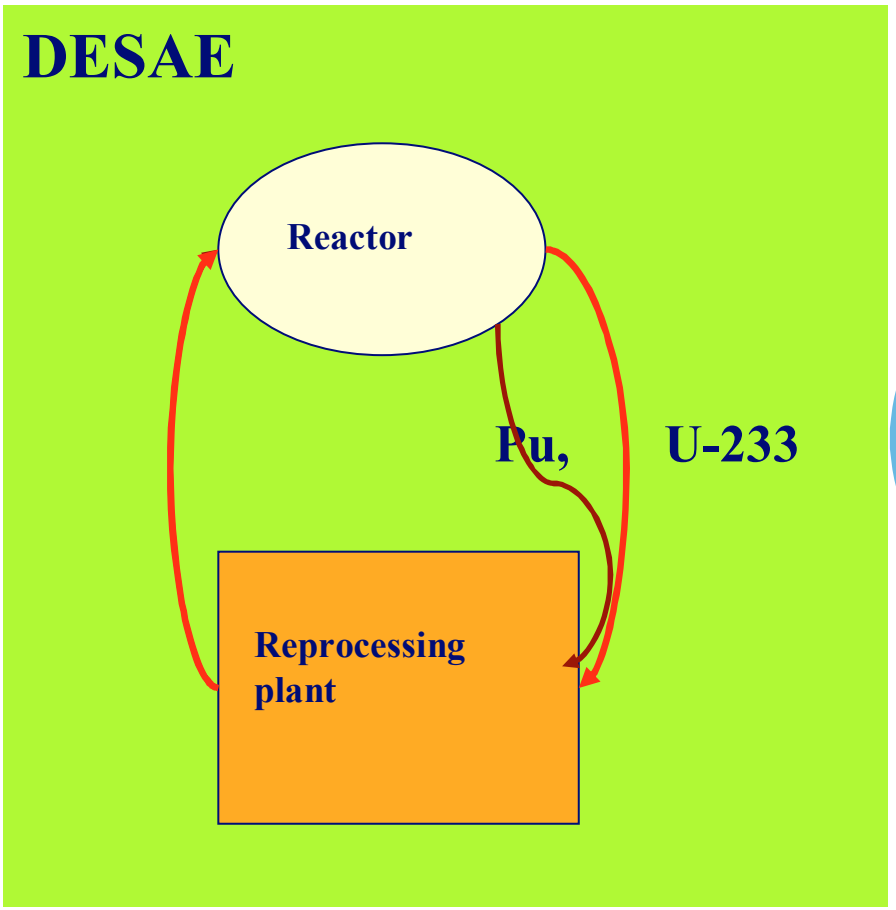
Fuel loading (core),
Fuel loading (top & bottom blanket),
Fuel loading (side blanket),

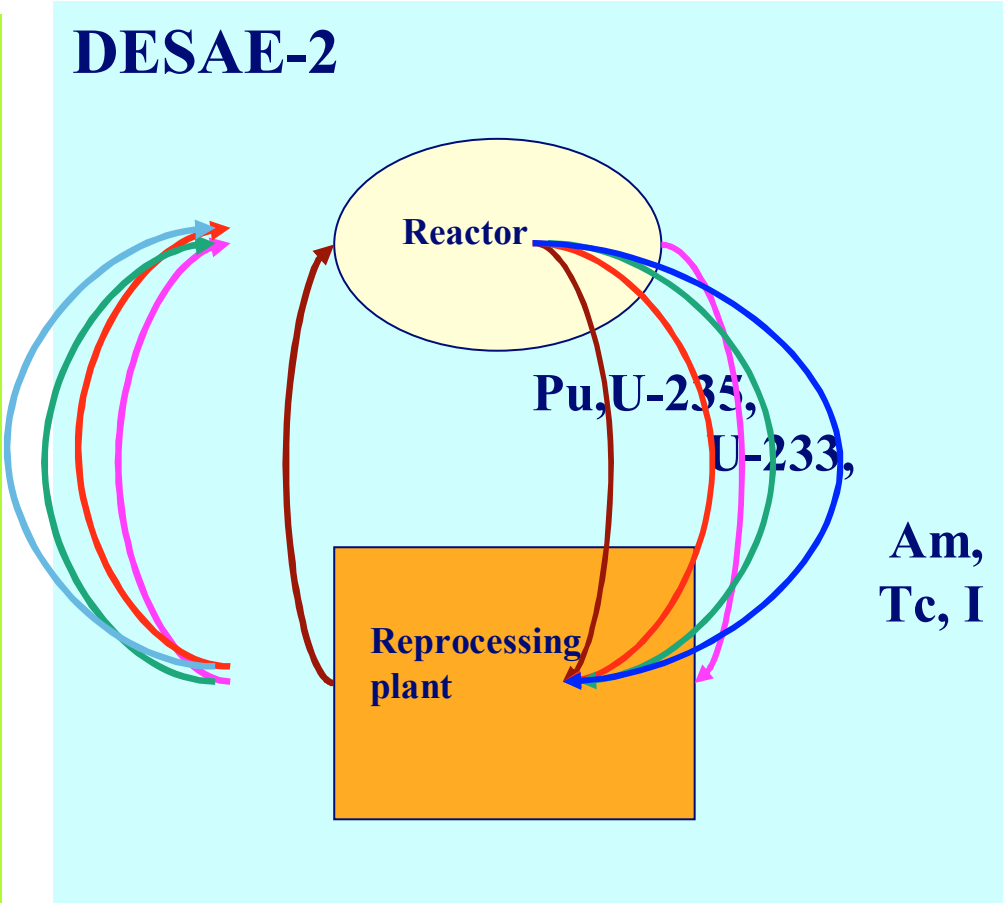
Company core, days
Company top & bottom blanket, days
Company side blanket, days

Isotopes

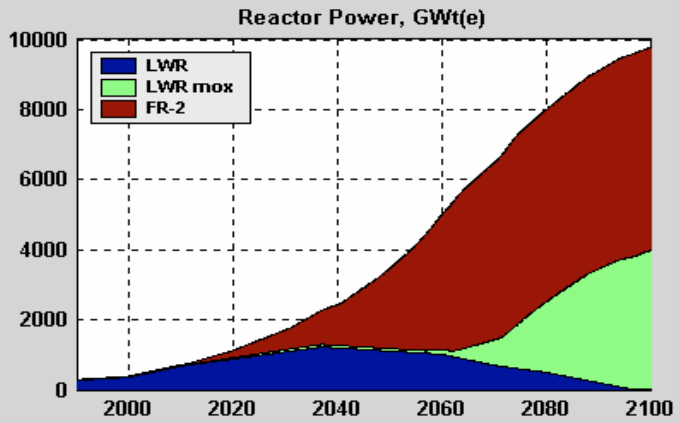
- Th-232
- U-232
- U-233
- U-234
- U-235
- U-236
- U-238
- Pu-238
- Pu-239
- Pu-240
- Pu-241
- Pu-242
- Am-241
- Cm-242
- I-129
- Tc-99
- Np-237
- xp1

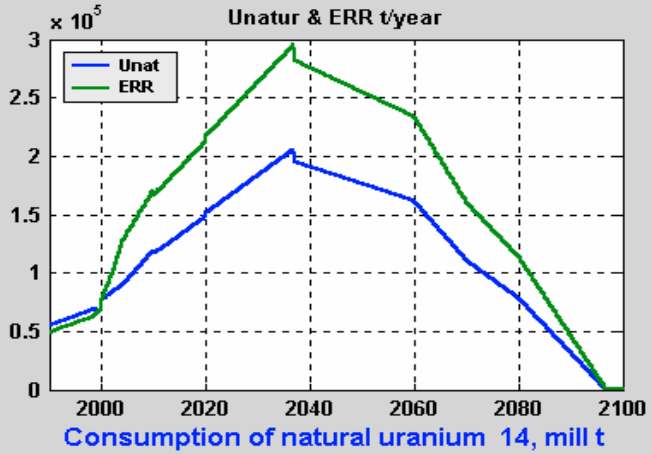
Fuel Cycle, the main difference DESAE & DESAE-2

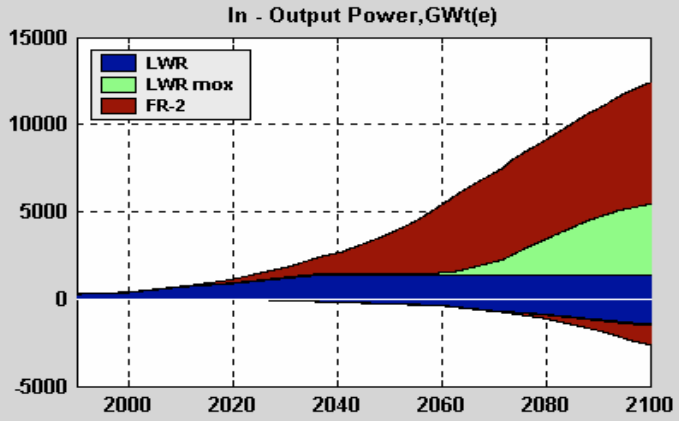


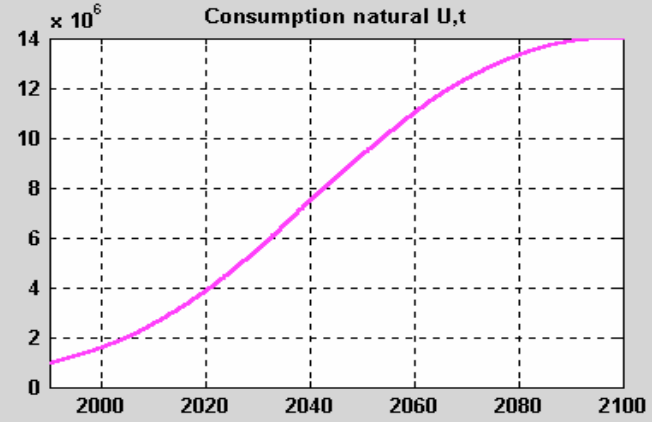


Multi-product INS allows to achieve 10000 GWe installed NE capacity, total U-consumption 14 mln t

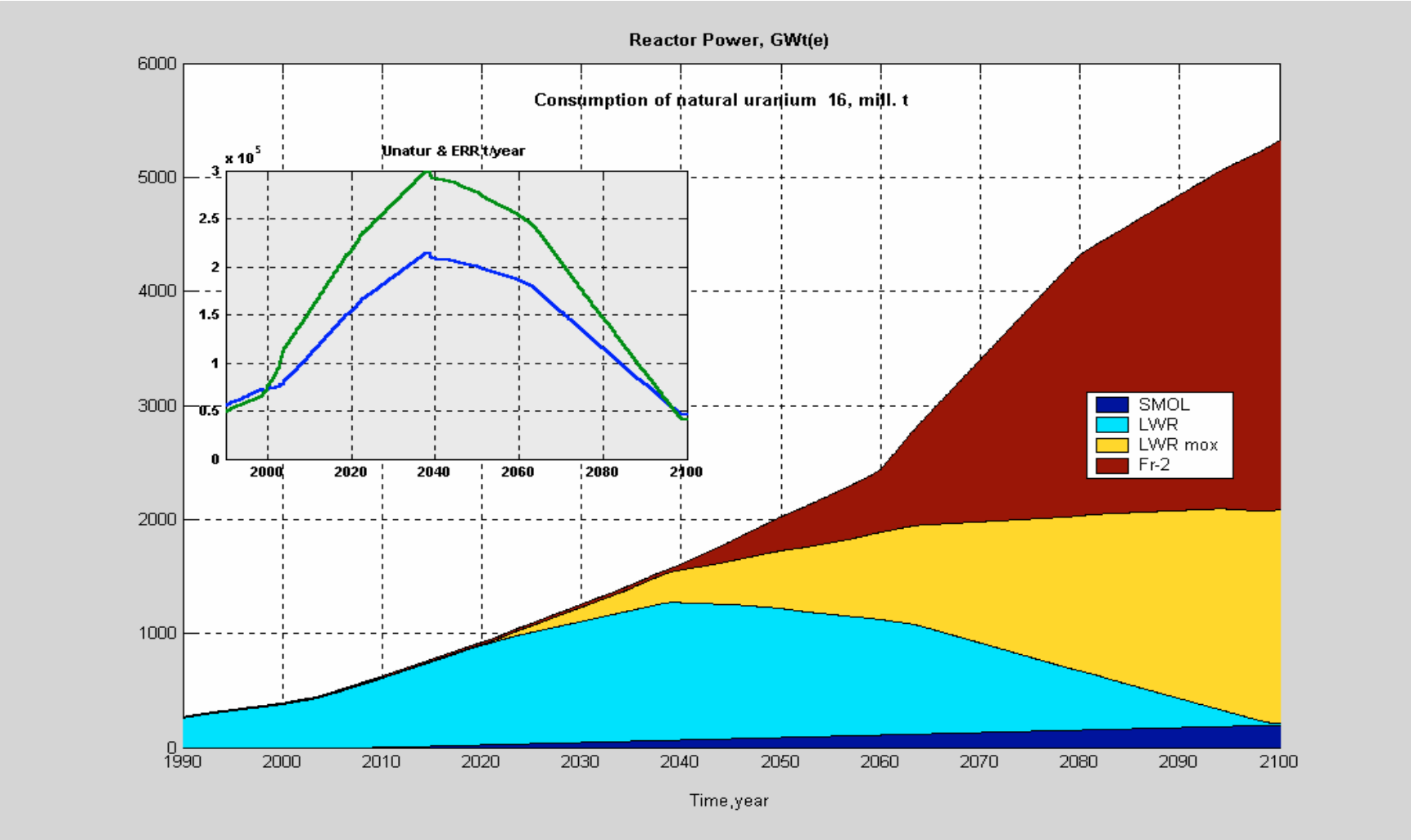








Small capacity reactors integrated in global INS, Scenarios B2



Outcomes of INPRO Case Studies

- *An interactive computer model DESAE (Dynamic of Energy System – Atomic Energy) has a potential to become a useful TOOL to perform energy planning studies. i.e:*
  - *- building of future energy scenarios, in particular in NE area*
  - *- predictive analysis of resource consumption and waste management of nuclear energy systems.*
  - *- estimation of investments in nuclear energy systems*

This Tool, when perfected, could be made available to the participants in INPRO related INS evaluation activities:

- *First, to serve as a learning tool*
- *later, for providing a rational and quantitative basis for evaluations under several INPRO UR and Criteria.*

- ***Complementary codes in the areas not covered by DESAE, such as safety, proliferation resistance, uncertainty management, assessment of potential of innovation need to be developed to enable comprehensive and quantitative assessment of INPRO methodology***

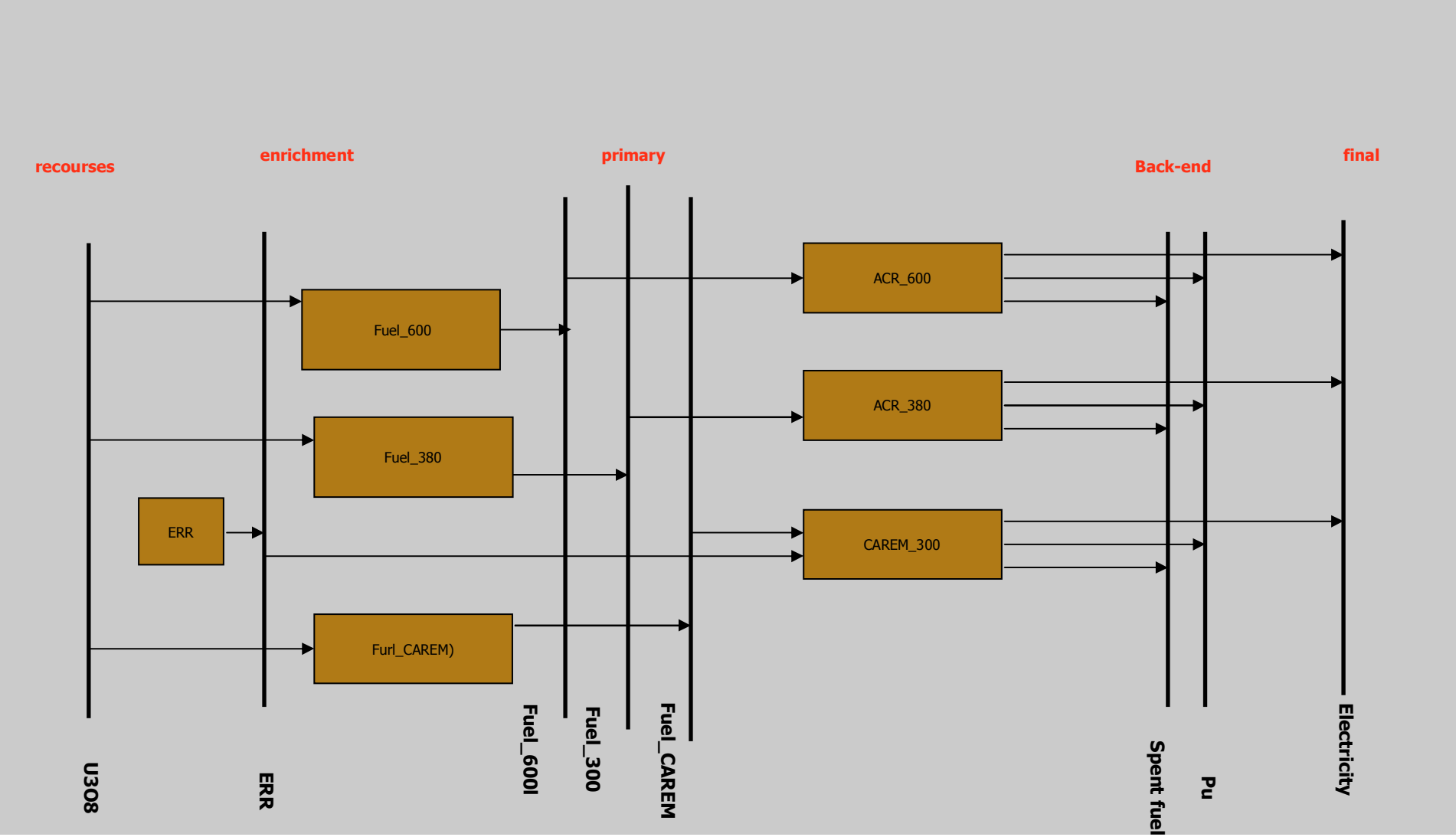
Integrated computer models for the analysis of energy development

DESAE and MESSAGE

Review of input and output data
in context of INPRO Methodology

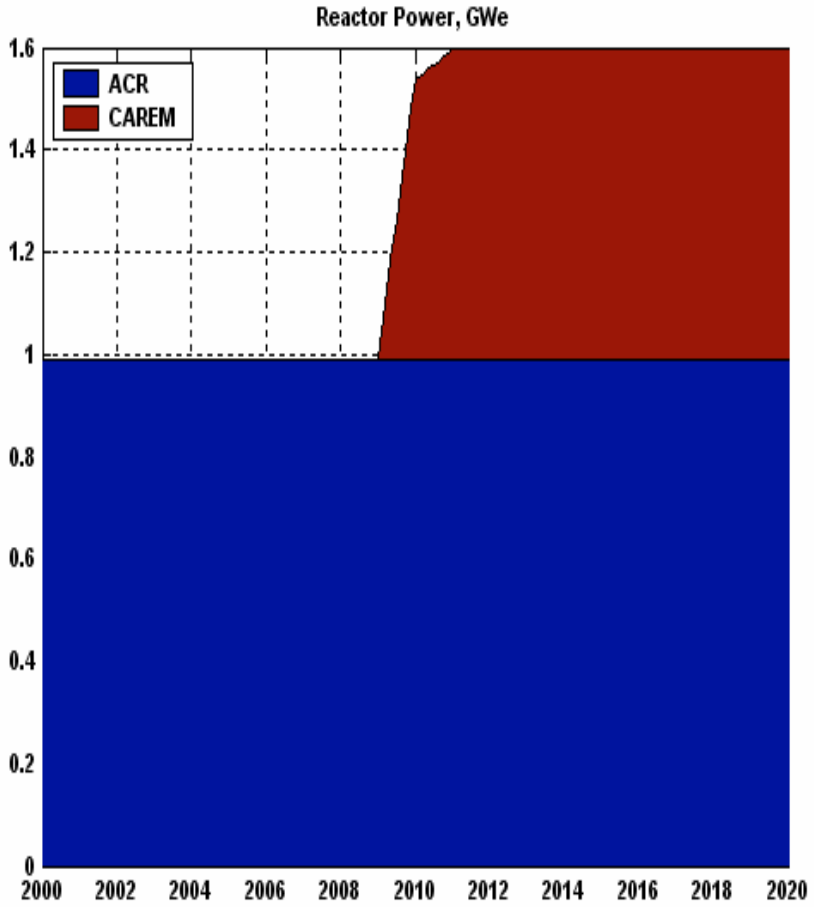
March 2005

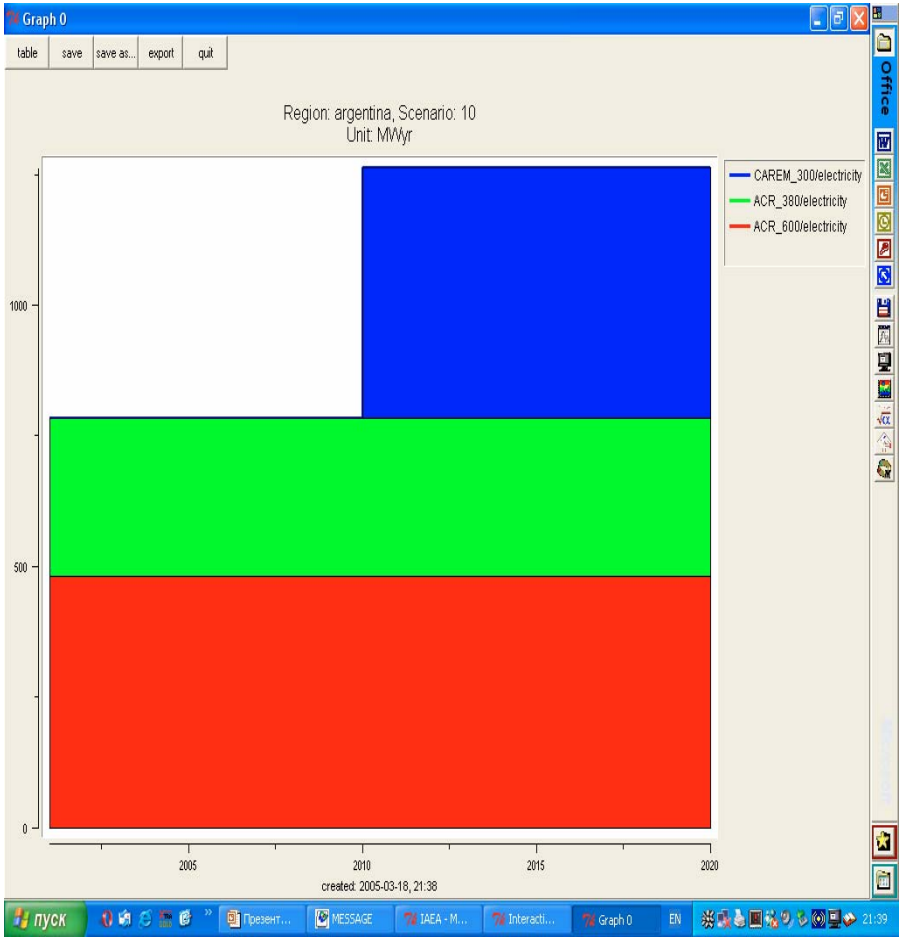
Model of Open fuel cycle (MESSAGE)



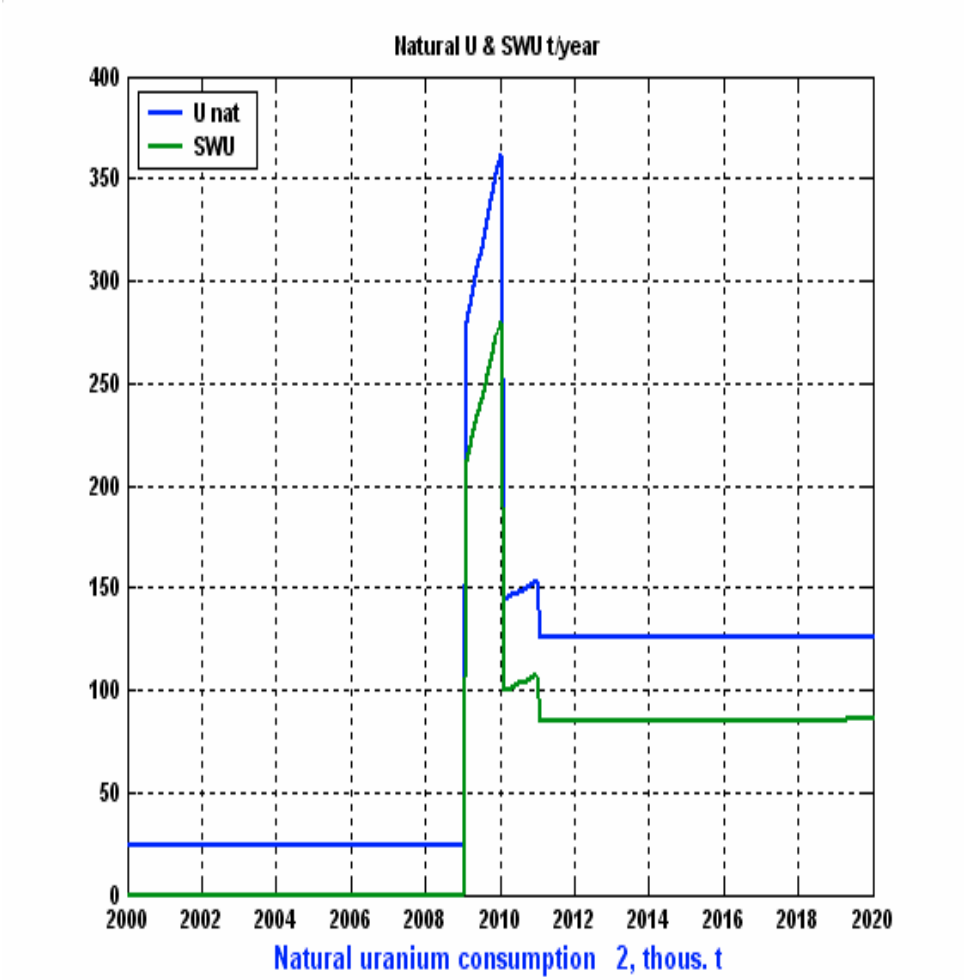
Energy demand for a nuclear energy system: *DESAE* and *MESSAGE*.

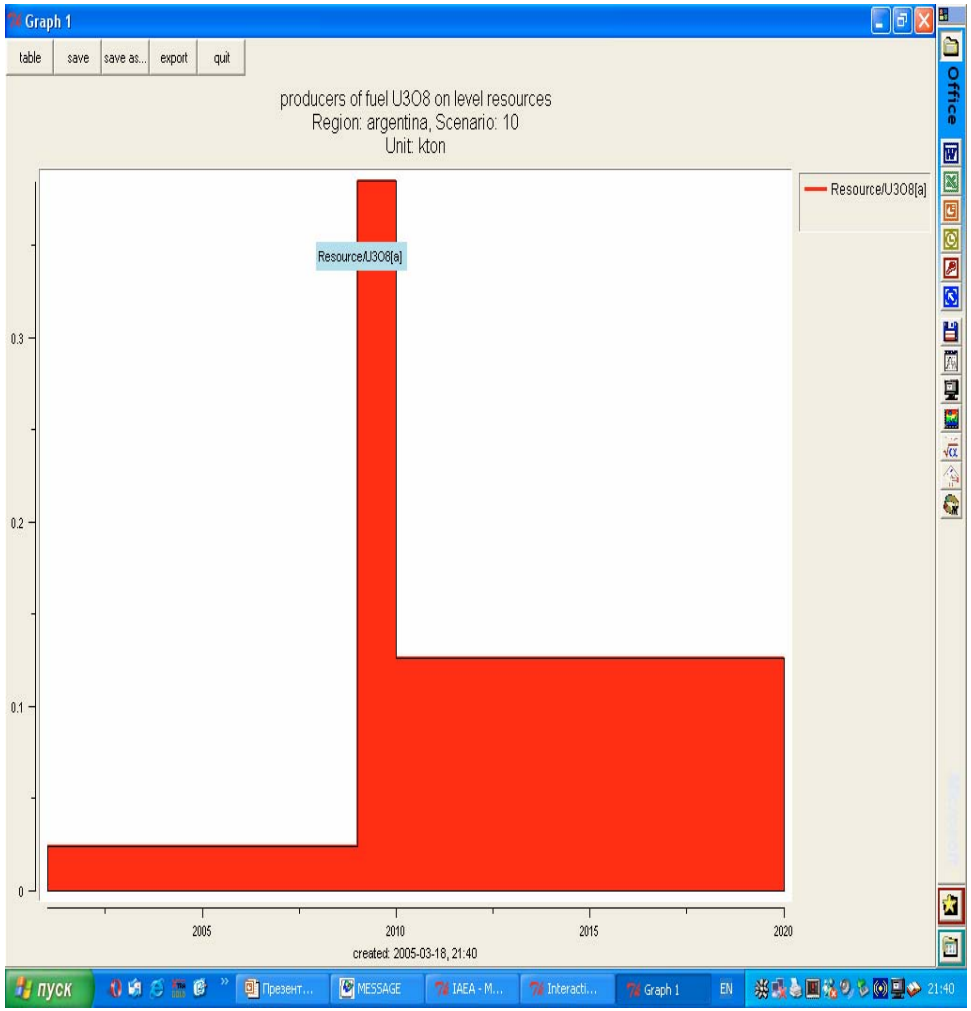
$$N[GWe] \Rightarrow 1 \cdot N \cdot \varphi \cdot 10^3 [MWe \cdot yr]$$



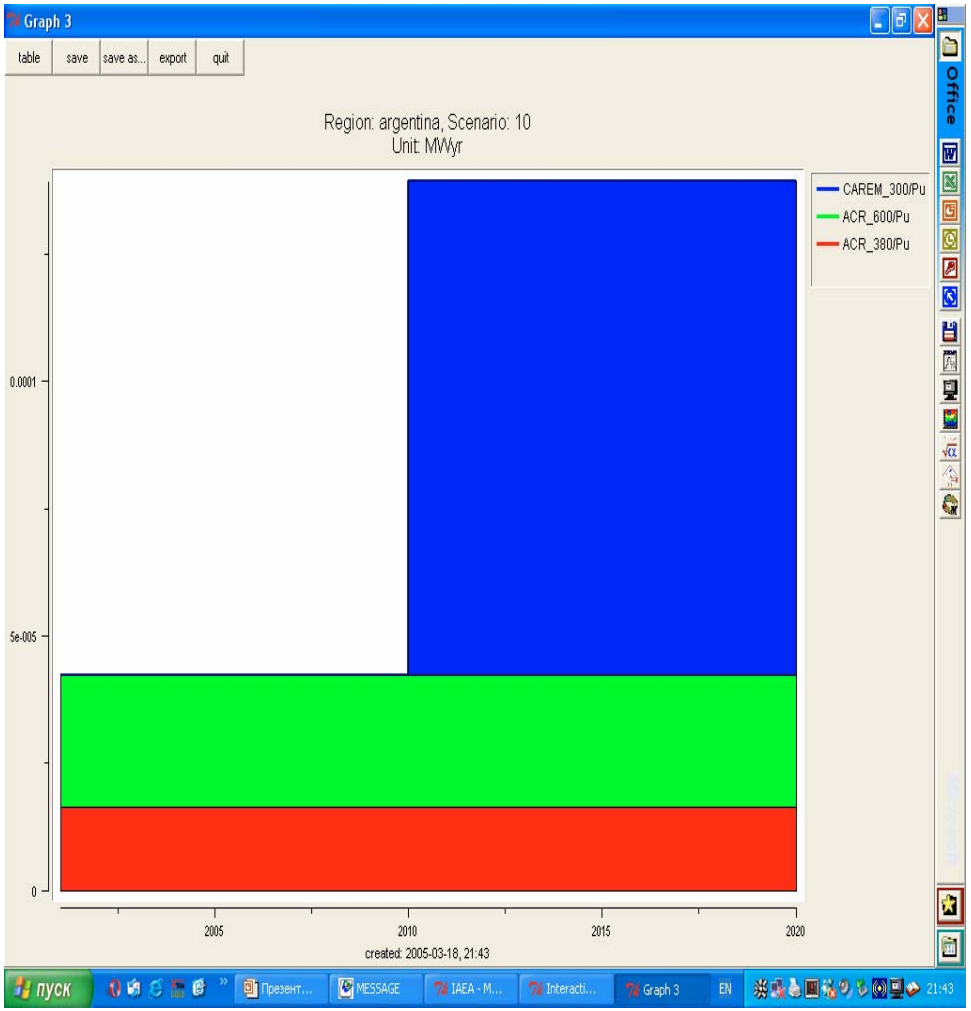


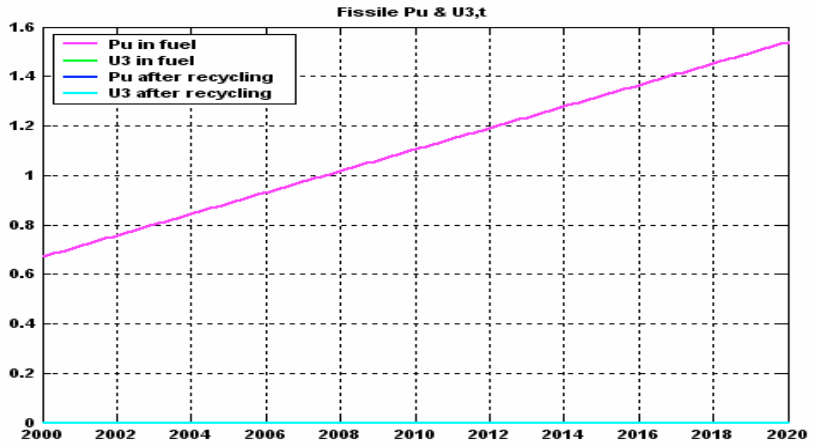
Natural Uranium and SWU

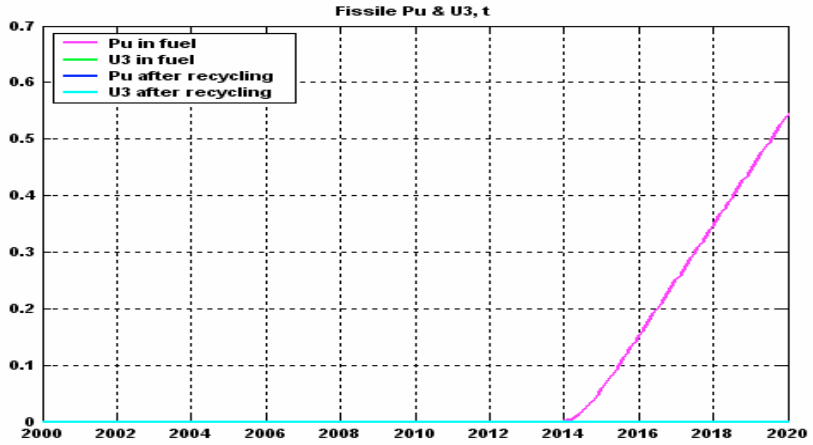




Production of fissile Pu and U233

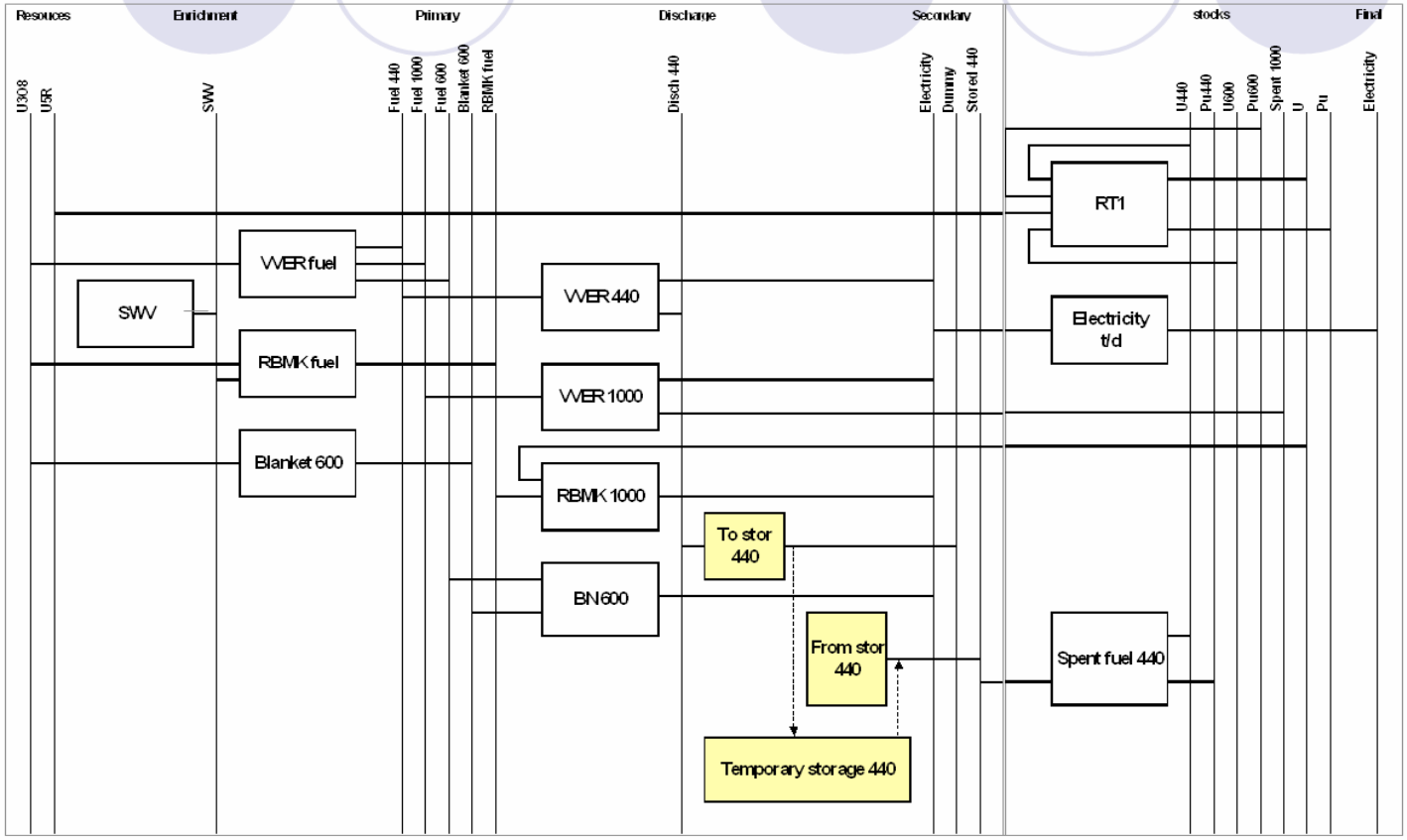




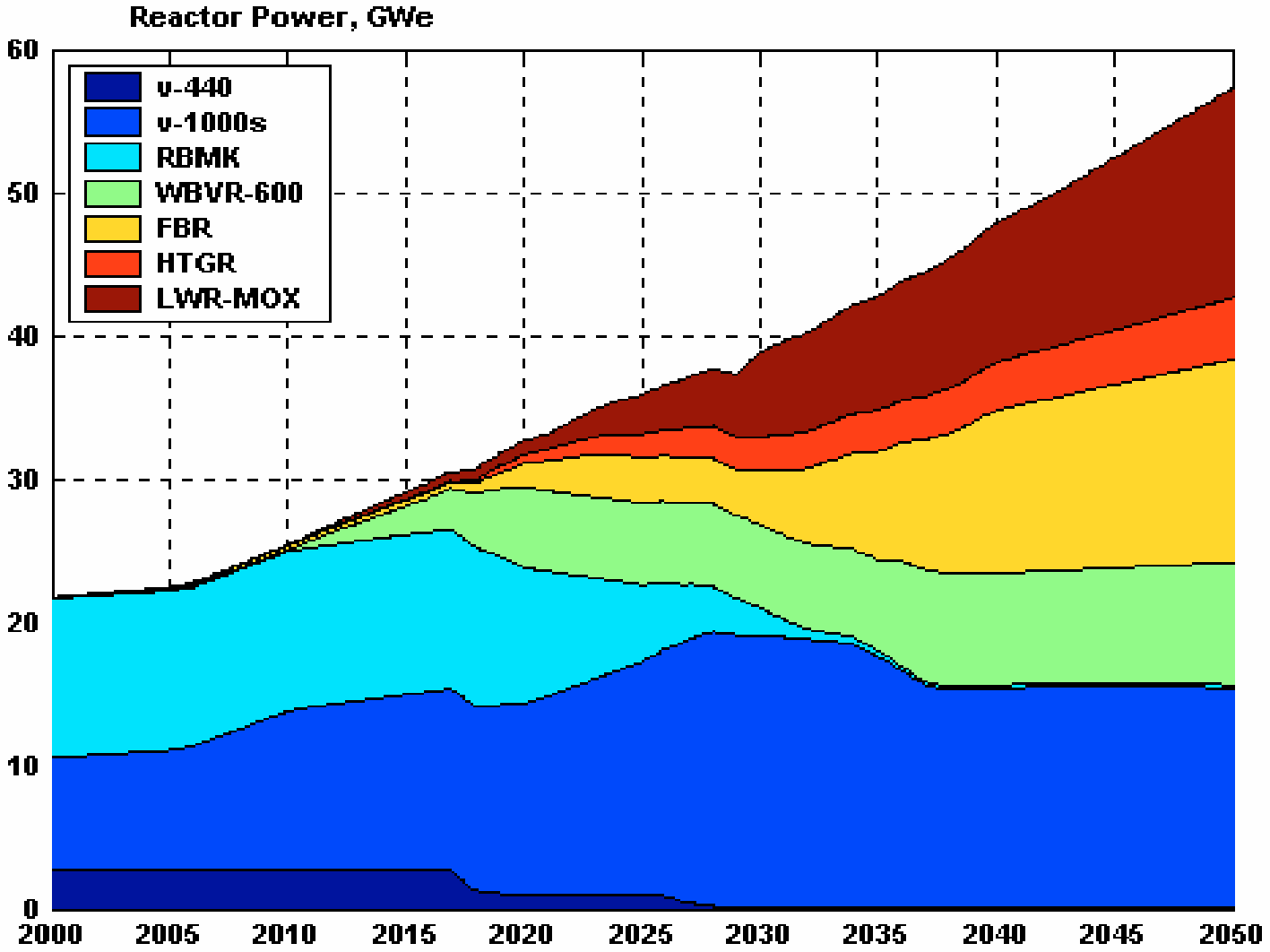


MESSAGE Model

Russian nuclear energy system network



Russian Federation Nuclear Energy Strategy up to 2050 on the basis of innovative technologies.



Natural U consumption- 360 000 tonne, Investments 97 billions $

Reference energy system