

DESAE (Dynamic Energy System- Atomic Energy) Integrated Computer Model for Performing Global Analysis in INPRO Assessment Studies

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INTRODUCTION

The Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was established to help to ensure that nuclear energy is available to contribute, in a sustainable manner, to the energy needs in the 21st century. In 2005, its membership continued to grow, with Ukraine and United States of America becoming additional members, and total INPRO membership now stands at 24.

The main objectives of INPRO are to:

- Help to ensure that nuclear energy is available to contribute in fulfilling energy needs in the 21st century in a sustainable manner; and
- Bring together both technology holders and technology users to consider jointly the international and national actions required to achieve desired innovations in nuclear reactors and fuel cycles.

INPRO's activities are intended to help to achieve one of the main objectives of the IAEA - to promote the development and peaceful use of nuclear energy. INPRO applies a carefully developed Methodology to

assess Innovative Nuclear Energy Systems (INS) and to define R&D needs and deployment strategies for the development of large-scale regional and global INS. The purpose is to match the opportunities and challenges of sustainable energy supply provided by nuclear energy (NE) to the global balance of demands and resources.

In order to make the most of the opportunities and face the challenges of nuclear energy (NE) in the event of its renaissance, IAEA Member States need to consider its large-scale development. INPRO proposes a global vision, which can provide justified guidelines for this development. Consequently global system analysis is needed for three reasons:

- To estimate the contribution of NE towards achieving sustainable development at a global level;
- To understand the boundary conditions for NE development (such as global energy demand, economic data, available resources, environmental issues, non-proliferation, safety, etc.);

- To identify effective institutional and technological development responses which will have a global impact.

In performing an INPRO assessment, the assessor must take into account a reference energy scenario or scenarios. For example, if the assessor were focused on energy supply in his state he would take into account a national energy scenario (or perhaps a more localized scenario based on a region within his country). Such a national scenario would also be expected to take into account global and/or regional considerations such as the global demand for uranium, reprocessing capacity, etc., and so would also have to use some elements of a regional or global scenario. If the assessor were interested in global energy supply as a component of sustainable development, he would necessarily utilize a broadly based scenario that takes into account various regions and country groupings to arrive at a global scenario.

The use of modelling tools is seen to be an important part of energy planning and of INPRO and the use of such tools will be integrated into the INPRO methodology as it is further developed. A number of modelling tools are currently available including IAEA codes such as MESSAGE and SIMPACT.

The DESAE (Dynamic of Energy System – Atomic Energy) code is being developed by the UNK Group at the Kurchatov Institute in Russia in the context of INPRO-project led by IAEA. The code is being used in INPRO assessment studies. A brief introduction on the model is presented.

DESCRIPTION OF THE ACTUAL WORK

The DESAE code

DESAE (Fig. 1) calculates the resources, both financial and material, required for a given combination of reactors to meet a specified supply of nuclear energy as a function of time. Thus, the user can study the practicality of a proposed system and material balances such as uranium demand as function of time, waste arising, plutonium recycling, etc. This model is oriented for the analysis of today's and future nuclear energy systems in various countries, regional or worldwide level. The second version of DESAE-2 is an interactive code which allows users to replace any characteristics of reactors or scenarios and compare results during the computations. User can consider open and closed fuel cycles (U-Pu, U-Th, Pu-Th and other combinations) including recycling of U and Th.

The code performs material flow analysis based on a user-defined deployment scenario of reactors and fuel cycle facilities. The code does not perform burn-up or core management calculations but bases the calculations on tabulated fresh and spent fuel compositions provided by the user (databases with this characteristics are available). For fast reactors the core, top, bottom and side blankets are considered as individual parts of reactor taking into account their isotopic compositions and cooling time before recycling. The tabulated fuel characteristics include data for equilibrium and start-up core compositions for the various reactors. The fuel composition is followed for 17 isotopes, i.e. ^{232}Th , ^{232}U , ^{233}U , ^{234}U , ^{235}U , ^{236}U , ^{238}U , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu , ^{237}Np , $^{242\text{m}}\text{Am}$, ^{244}Cm , ^{129}I , ^{99}Tc , with one additional group for the other fission products. The code also calculates integral and differential

consumption of different materials in an INS, e.g. Fe, Cu, Al, Zr, C, electricity, heavy and light water. Value of electricity consumption allows users to consider other INSs like ADS and fusion systems. User should provide a certain part of input data to perform such specific studies.

DESAE allows modeling 7 reactor types in parallel in once simulation with all of them having any chain of fuel exchange between the reactors. These fuel exchange paths need to be defined by the user. The fuel cycle representation in DESAE is done with 4 fuel cycle facilities, without tracing losses in these facilities. The quantity of fission products and decay heat in

spent fuel is calculated but repository needs are currently only defined by the volume of materials to be stored. Proliferation risk is assumed to be dependent on the volume of so-called relevant materials, i.e. Pu.

The economic analysis within DESAE considers leveled cost of energy calculation based on the capital costs for reactors and nuclear fuel cycle facilities, the operation and maintenance costs and the calculated fuel cycle costs.

Graphical user interface allows easy input and output of the results of INS assessment as well as obtain any calculated values in form of EXEL files.

DESAE: Input and Output data

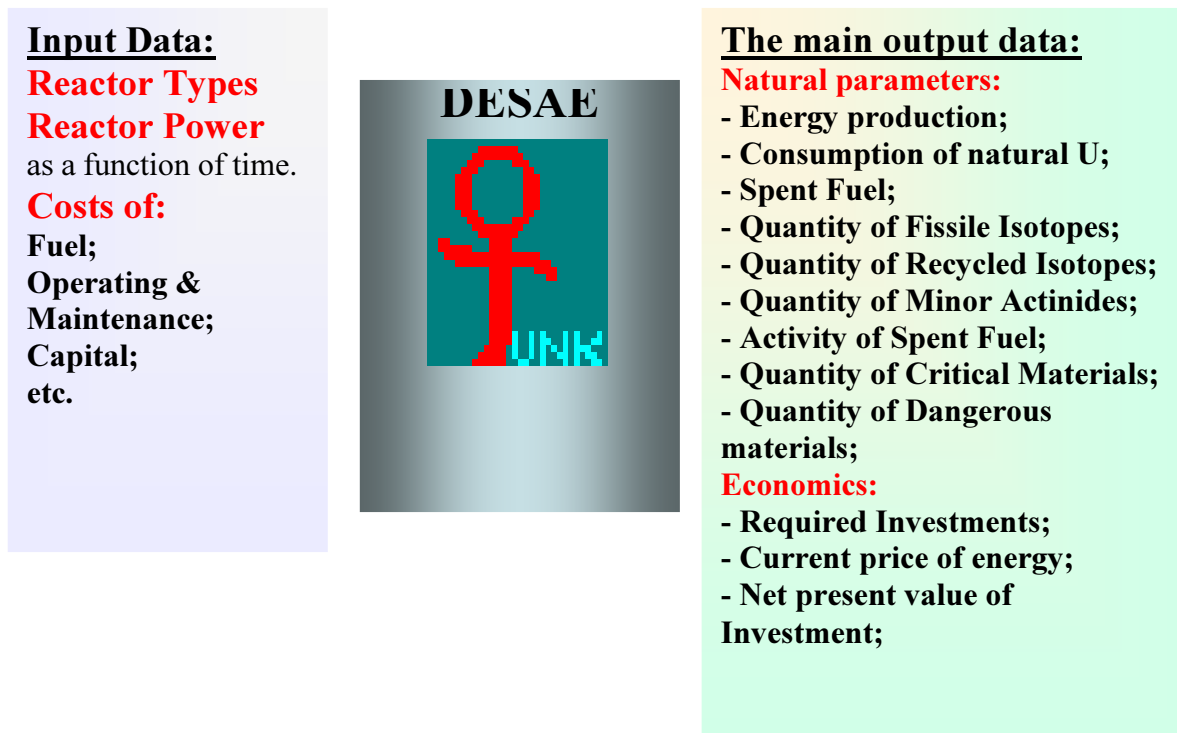


Figure 1. Main input and output data of DESAE code.

DESAE is an interactive code, as illustrated in Figure 2. The user specifies a given demand for nuclear energy — at present only nuclear electricity can be modelled — and the combination of

reactor types that will be used to supply this energy, the fuel cycles to be used and the costs (overnight construction cost, fuel cost, operating costs, etc.) for each. The code then calculates a variety of parameters such as the consumption of natural uranium as a function of time, quantities of spent fuel and other materials such as actinides and recycled materials; the consumption of critical materials such as zirconium, the investment required, the cost of energy etc, in near real time. The user can then seek to optimize the nuclear

energy system by varying the mix of reactor types and fuel cycles. The code does not utilize an optimization function but does provide information to the user to assist the user in the choice of alternatives.

The user can choose from a variety of reactors that are in use and that are under consideration for development, including LWRs, PHWRs, fast reactor, HTGRs, etc. Users can also specify a new reactor type by supplying information on its relevant characteristics.

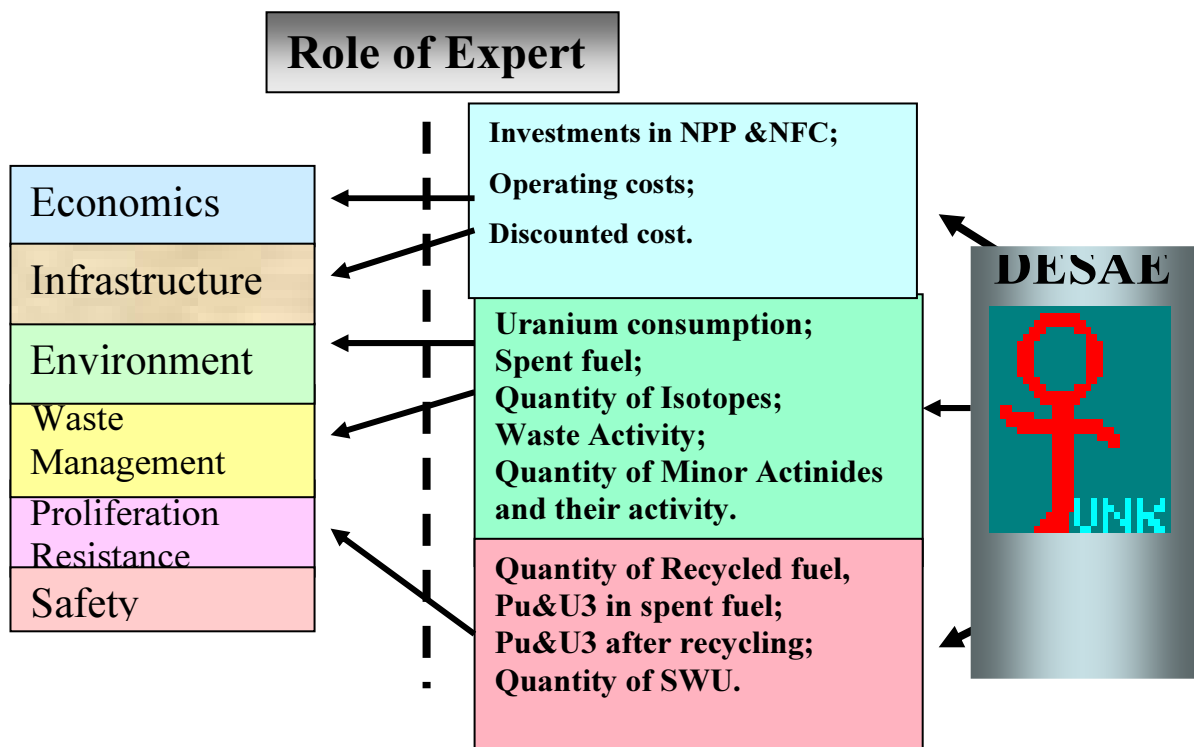


Figure 2. Interactive role of expert in using the DESAE code.

DESAE is currently being used in national, regional, and global energy studies for the following:

- Calculating material and financial resources required for different nuclear energy deployment strategies, which is of interest in itself and which can be used in INS assessments, e.g. in environmental material flow analyses;
- Inter-comparing different nuclear energy systems and components

thereof, including the evaluation and demonstration of the benefits of various option for closed fuel cycles and the identification of the reactor characteristics that are most important for a given system;

- Comparing different INS structures on a regional and global basis to identify complementarities and synergisms among systems of interest to different Member States, in both technology and in infrastructure.

In this way DESAE will assist in identifying possible paths to a globally sustainable nuclear energy system based on diverse national and regional components.

On-going development of DESAE

As has been noted DESAE as currently developed treats only nuclear electricity (Figure 10.3). In the future it is foreseen that DESAE will be expanded to include, for example:

- Non-electrical NE applications such as the supply of heat and hydrogen, desalination, and transmutation of minor actinides;

- Modules for other source of energy supply, namely, gas, oil, coal, hydro, and renewables;
- Modelling of interregional transportation of fuels and other raw materials, nuclear waste, reactor systems, etc.;
- Modules to correlate outputs with the values of INPRO Key Indicators; and to include
- Feedback from learning into the costs used in DESAE.

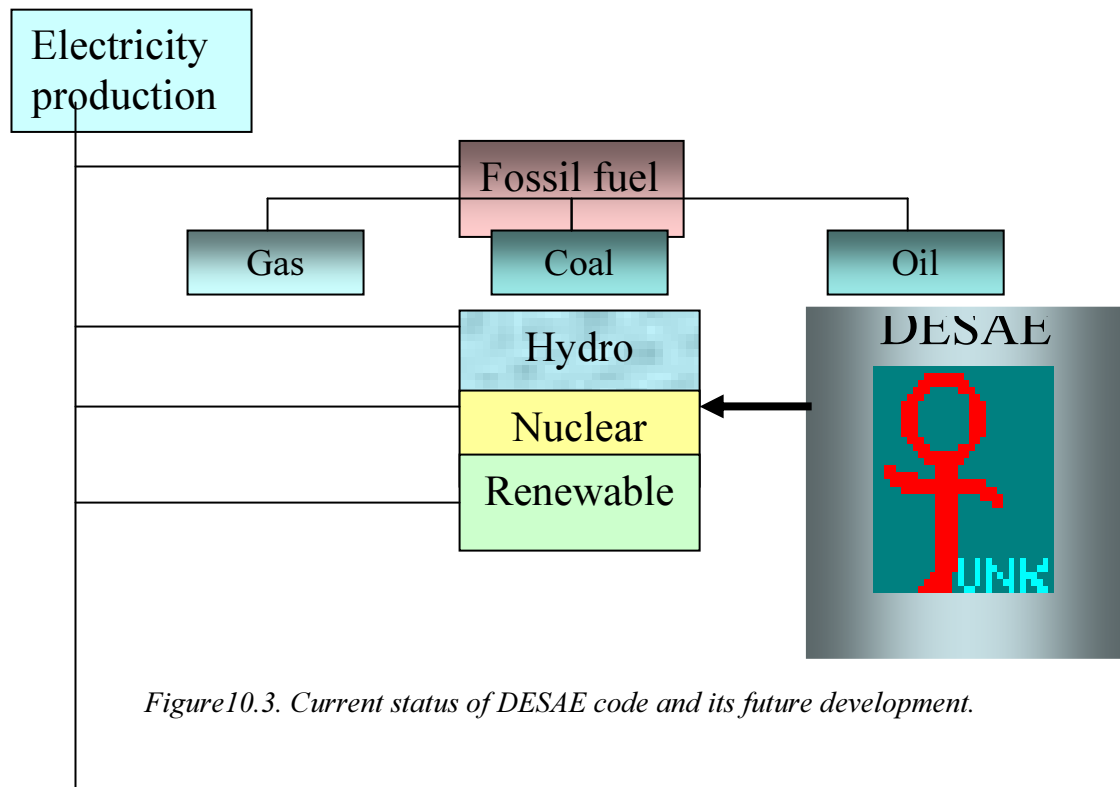


Figure 10.3. Current status of DESAE code and its future development.