MINISTRY OF ENERGY AND COAL INDUSTRY OF UKRAINE

ЕНЕРГО ENERGO АТОМ

NATIONAL NUCLEAR ENERGY GENERATING COMPANY

Strategic Nuclear Energy Planning of Ukraine in the Framework of INPRO

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GC IAEA, Vienna 17-21 September 2012

Ukraine's Participation in the INPRO Project

Ukraine joined the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) in 2005.

In 2008 Ukraine initiated a National Research to assess the innovative nuclear energy system of Ukraine using the INPRO methodology in compliance with the Energy Strategy of Ukraine until 2030.

While involved in INPRO activities, the Ukrainian specialists participated in the joined research "NESA Based on Closed Nuclear Fuel Cycle with Fast Reactors".

In 2008 Ukraine joined GAINS project (Global Architecture of Innovative NES based on Thermal and Fast Reactors Including Closed NFC).

Strategic Nuclear Energy Planning of Ukraine Within the Framework of INPRO

Ukraine initiated its own Domestic Research to assess the prospects of development of its nuclear energy system (NES) for the period until 2100.

The key purposes of the Research:

- Identify the nuclear share in the total energy pie of Ukraine.
- Select a sustainable innovative nuclear energy system of Ukraine (Innovative NES) based on the research conducted using the INPRO Methodology.
- Master and utilize INPRO (TECDOC-1575) methodology and international modeling tools.
- Develop a draft commissioning schedule for new capacities and infrastructure development in Ukraine until 2100.
- Identify next steps to ensure sustainable development of the nuclear power industry in Ukraine

Strategic Nuclear Energy Planning of Ukraine Within the Framework of INPRO

The Domestic Research consists of the following stages :

- Development of scenarios of electricity production/consumption in Ukraine, with account of economic growth forecasts, energy saving concepts and possible development of alternative energy sources for the period until 2100 within the domestic energy system.
- Development and modeling of Innovative NES options with thermal and fast reactors within a closed NFC.
- Analysis, using the INPRO methodology TECDOC-1575, of INES options for sustainable development.
- Preparing a Final Report and its submission to the IAEA.

Strategic Nuclear Energy Planning of Ukraine Within the Framework of INPRO

In support of its Domestic Research, SE NNEGC "Energoatom" in cooperation with the IAEA initiated a project on "Strategic Nuclear Energy Planning Within the Framework of INPRO" (October 2010).

This project helps to make use of IAEA expertise and tools while implementing the Domestic Research on NES development in Ukraine in the long term. Thus, via the specified two projects, Ukraine has been implementing the Unified Joint Project in the area of strategic Innovative NES planning.

Strategic Nuclear Energy Planning of Ukraine Within the Framework of INPRO

IAEA's assistance to Ukrainian experts in support of the Unified Joint Project:

- Transfer of the latest versions of MESSAGE, MAED, DESAE modeling codes and NEST, a package for NESA.
- An expert review, followed by recommendations, of the preliminary report on the forecast of the domestic electricity supply/demand with account of the potential nuclear power share.
- A two-week training for Ukrainian experts on the use of IAEA programming tools (MESSAGE, MAED, DESAE) and NES planning methods.
- A training of Ukrainian experts on INPRO methodology in the areas of Economics, Infrastructure and radioactive waste Management.
- Assistance in compiling of input data for modeling of NFC options and economic parameters.

Stages of the Unified Joint Project. Deliverables

- Stage 1: Electricity production and consumption scenarios for Ukraine for the period until 2100 given development of the national power industry.
- Stage 2: Development and modeling of the Innovative NES with thermal and fast reactors and closed NFC.
- Stage 3: Analysis, using the INPRO methodology TECDOC-1575, of the Innovative NES options for sustainable development.

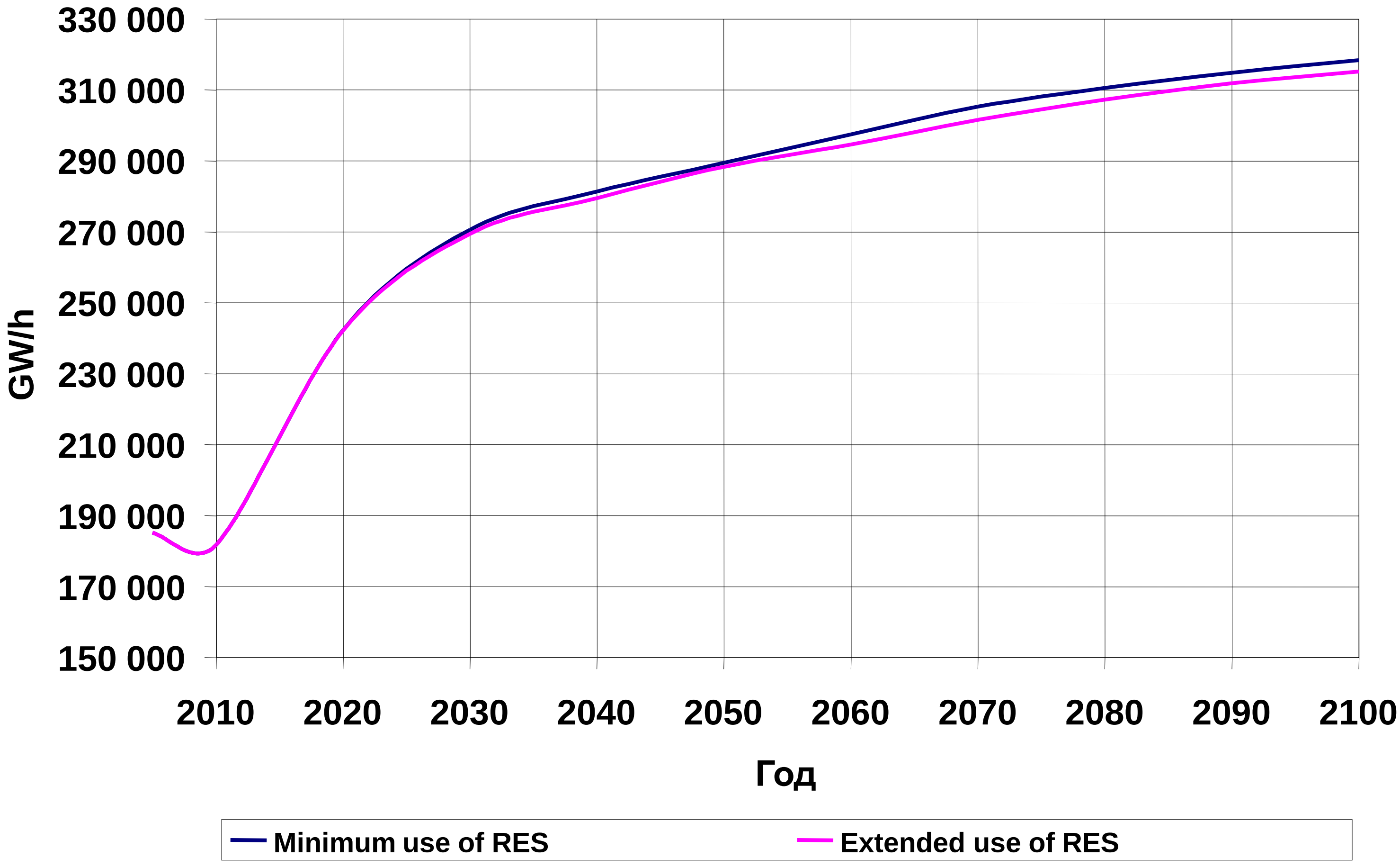
Development of Electricity Production and Consumption Scenarios for Ukraine for the Period Until 2100.

The initial stage included generation of electricity production/consumption curves (for scenarios of minimum and extended use of renewable energy sources, RES) the code TIMES-Ukraine was used (Institute for Economy and Industry, National Academy of Sciences of Ukraine).

Ukrainian experts performed an extended assessment of possible non-nuclear electricity generation (coal, gas and oil, wind and solar generations) in Ukraine for the period until 2100.

Based on the generated curves of electricity production/consumption, the existing energy system of Ukraine was modeled using MESSAGE code.

Electricity Production/Consumption Curves



Modeling Innovative NES Scenarios with Thermal and Fast Reactors.

Review of possible scenarios of the Innovative NES development in Ukraine using MESSAGE code.

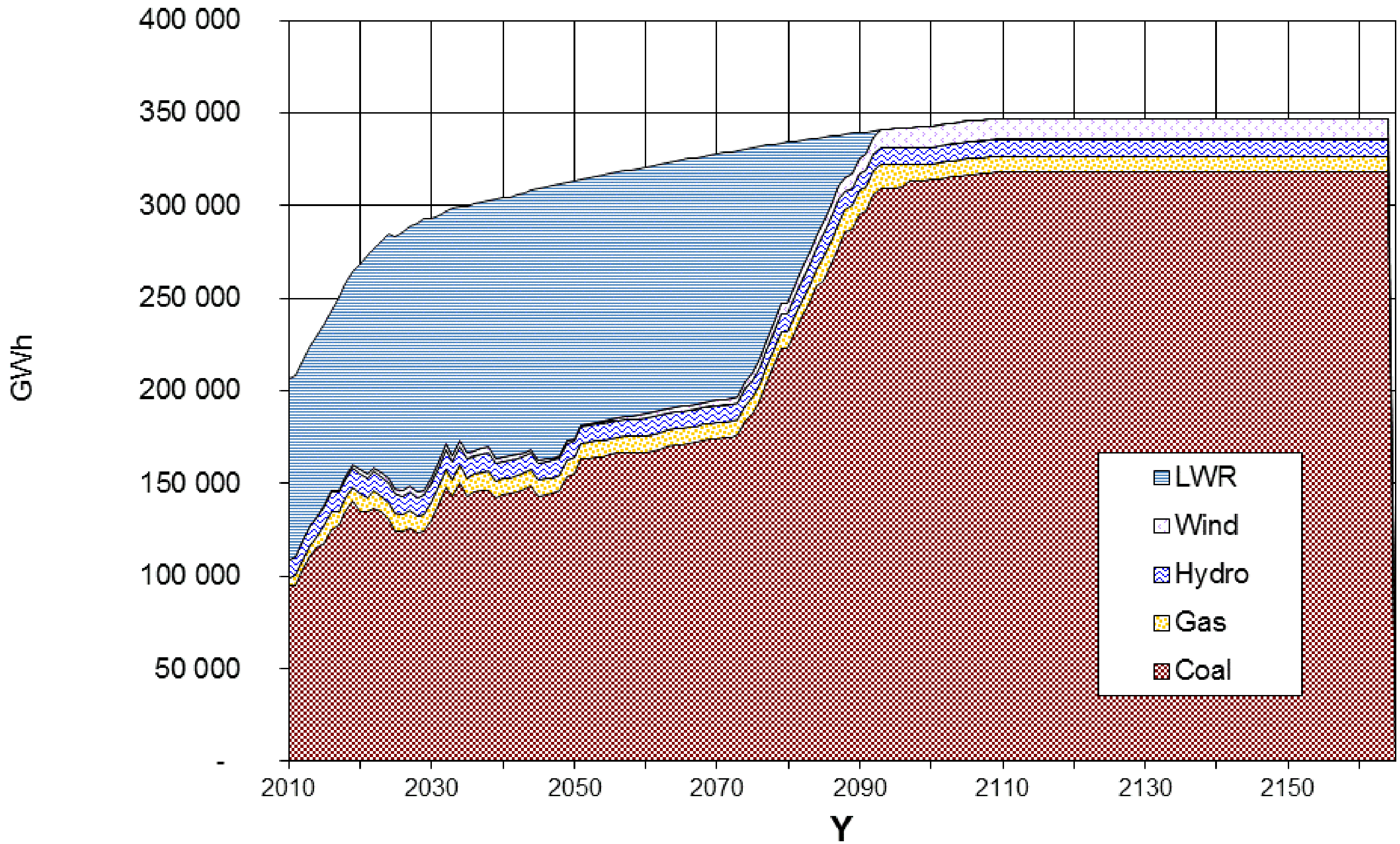
- NFC with light-water reactors.
- NFC with heavy-water reactors.
- NFC with fast reactors.

Example of an Open NFC with Light-Water Reactors. Scenario for Exclusive Use of Domestic Uranium

NFC "as it is" represented by the VVER RIs including units 3 and 4 of KhNPP under construction and other units of evolutionary VVER-1000 design with increased design service life.

Given the specified configuration, expected are approximately 25 k tons of SNF generated for the whole operating life. The model envisages the possibility of SNF final disposal.

Example of an Open NFC with Light-Water Reactors. Scenario for Exclusive Use of Domestic Uranium



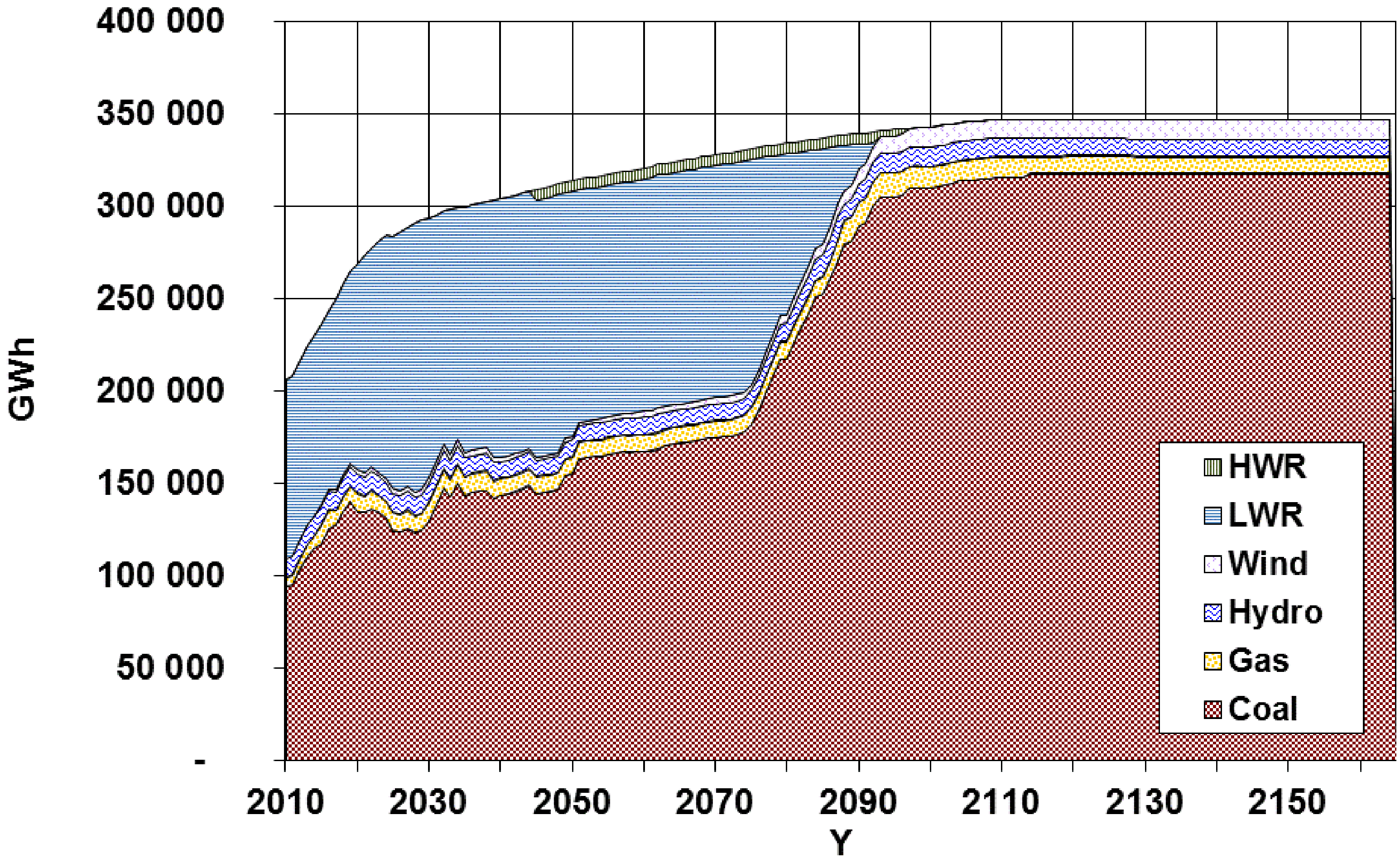
Example of an NFC with Heavy-Water Reactors

This scenario considers light-water reactors of the existing designs and heavy-water reactors using natural uranium.

Heavy-water reactors generate larger amounts of SNF as compared to light-water reactors. Thus, an NFC with one single heavy-water reactor generates 30 k tons of SNF: 25 k tons generated by light-water reactors (17-18 k MW) and 5 k tons generated by a heavy-water reactor of maximum 1 MW capacity.

Although systems with HWRs using natural uranium require less natural uranium, there are no substantial savings of the natural uranium resources in a given NFC explained by a minor share of heavy-water reactors.

Example of an NFC with Heavy-Water Reactors (HWR)



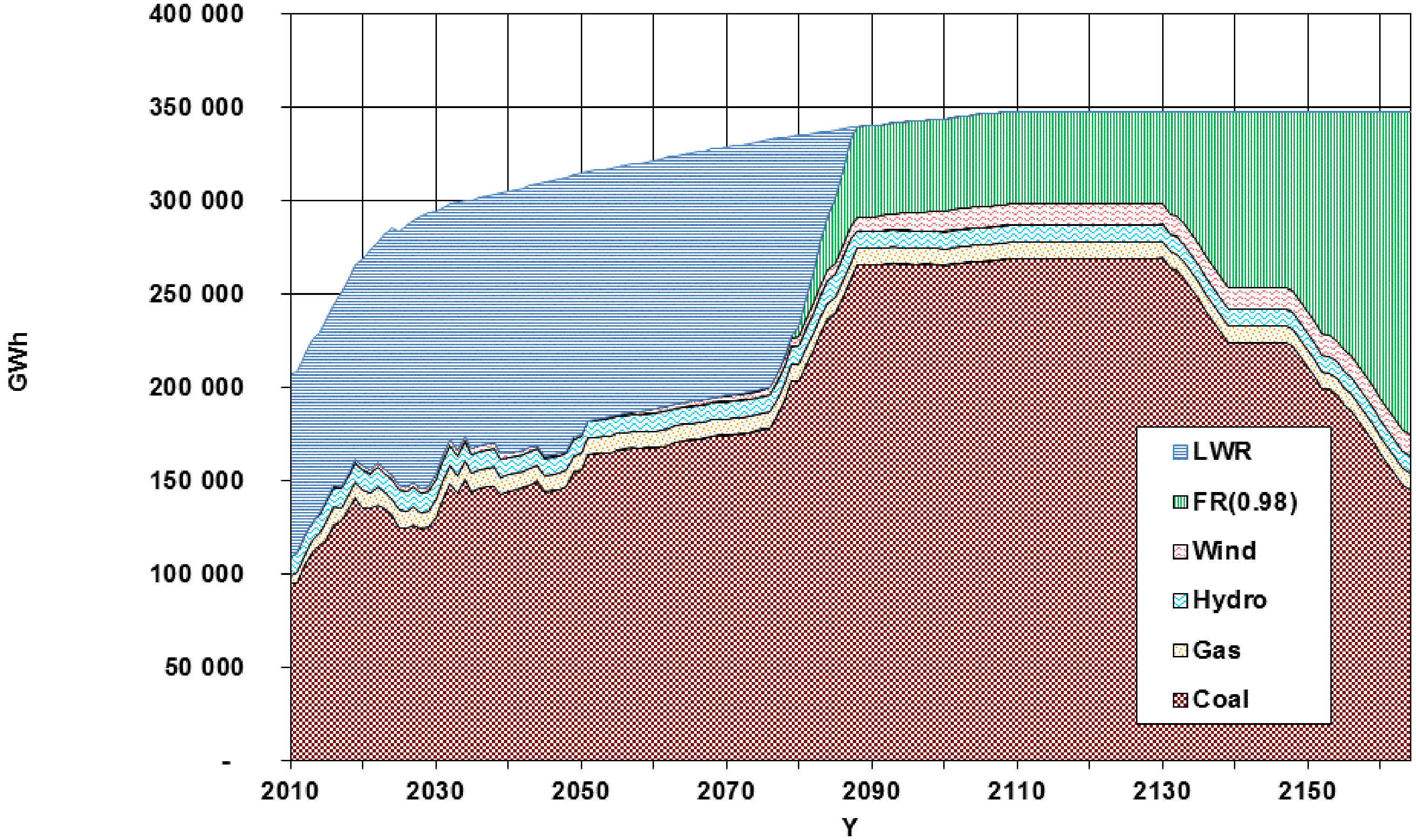
Example of a Closed NFC with Fast Reactors (Breeding Ration~1).

The nuclear power share decreases in 2080-2090s as the natural uranium resources get exhausted, while commissioning of fast reactors starts in early 2090s. The reason for such a delayed introduction of fast reactors is high reprocessing costs for SNF coming from light-water reactors and fabrication costs of fast reactor fuel.

Similar to scenario with light-water reactors, the peak of commissioning of capacities is expected for 2020 – 2030.

By 2090, light-water reactors are expected to accumulate approximately 25 k tons of SNF, which is almost similar to the amount of SNF in the open NFC. It is explained by operation of exclusively light-water reactors until natural uranium resources are exhausted.

Example of the Closed NFC with Fast Reactors (Breeding Ratio ~ 1). Exclusive Use of Domestic Uranium



Analysis, Using INPRO Methodology TECDOC-1575, of Innovative NES Scenarios for Sustainable Development.

- A final stage of the Research will include an assessment of NES options in the three areas as defined in the INPRO TECDOC-1575 methodology:
  - Economics
  - Infrastructure
  - RAW Management
- Ukrainian experts are just initiating the assessment. Results expected in 2013.
- A training on the use of INPRO methodology was conducted in May 2012, with IAEA experts involved;
- Ukrainian experts have prepared a preliminary analysis of the domestic nuclear energy system development in each of the areas defined in the INPRO methodology.

Tasks in Economics

A preliminary analysis of assessment of the "Economics" has revealed the following challenges:

- Low investment attractiveness of the nuclear power industry
- No sufficient operating history of new designs currently available on the market (high risk of investment)
- No commercial Generation IV designs

Tasks in Infrastructure

- Ukraine has a developed infrastructure of nuclear power industry (uranium mining, construction and operation of NPPs, SNF and radioactive waste management).
- A preliminary analysis has shown no significant challenges related to the assessment of this area.
- Public acceptance on issues related to nuclear power industry development

Tasks in Waste Management

“Radioactive Waste Management”: a preliminary assessment has shown a significant focus on radioactive waste and SNF management in Ukraine. Most recent projects include :

- Initiation of construction of the Central Spent Nuclear Fuel Storage Facility (CSNFSF) to accommodate SNF of Ukrainian NPPs.
- Designing of a storage for vitrified HLW from SNF reprocessing to be returned from the Russian Federation.
- Construction of solid and liquid radioactive waste treatment facilities

An assessment on “Radioactive Waste Management” can be complicated as related to its SNF component (a “deferred decision” concept).

Conclusions

An integrated approach to Research staging proved efficient:

- NES planning.
- Innovative NES assessment.

Participation of PESS/INPRO experts ensures high-quality performance and correct deliverables.

A project designed to support the NESA permits efficient accomplishment of the defined tasks, provides recommendations of IAEA experts and ensures further analysis of the results.

Conclusions

- An important step in arrangement of activities is transfer of IAEA modeling codes and respective training.
- Use of INPRO methodology in a Research helps to identify challenges and develop action plans to attain sustainable development of NES in future.

Thank you for your attention!