Nuclear Energy System of Ukraine for near and medium term (2030 - 2035) and International Collaboration in developing sustainable NES of Ukraine

*L. Benkovskyi*
National Nuclear Energy Generating Company of Ukraine “Energoatom”

INPRO Dialogue Forum 11 “Roadmaps for a Transition to Globally Sustainable NES”

20-23 of October, 2015
IAEA, Vienna, Austria
There are 4 NPPs in operation in Ukraine, namely:

- Zaporizhzhya NPP
- Rivne NPP
- Khmelnitsky NPP
- South-Ukraine NPP
ZAPORIZHZHYA NPP
SOUTH – UKRAINE NPP
Будівництво енергоблоків № 3 та 4 Хмельницької АЕС

На сьогодні порівняно з початковим проектом будівельна готовність енергоблоків оцінюється:

 енергоблок № 3 – 75%
 енергоблок № 4 – 28%

Будівництво енергоблоків № 3 та 4 Хмельницької АЕС за початковим проектом (потужністю 1000 МВт кожний, з реакторною установкою ВВЕР-1000/В-320) розпочалось у 1986 р., але у 1990 р. було призупинено дією мораторію на будівництво АЕС.
Nuclear energy as part of the national energy mix of UKRAINE

NUCLEAR POWER PLANTS OF UKRAINE

SE NNEGCG ENERGOATOM IS THE OPERATOR OF 4 RUNNING NUCLEAR POWER PLANTS WITH A TOTAL INSTALLED CAPACITY OF 13 835 MW

**Rivne NPP**
- Electricity production for 8 months 2015 - 12.0 bln kWh (20.8% of the overall electricity production by SE “NNEGCG “Energoatom”)
- Number of employees - 7 844

**Khmelnityskyi NPP**
- Electricity production for 8 months 2015 - 10.4 bln kWh (18.0% of the overall electricity production by SE “NNEGCG “Energoatom”)
- Number of employees - 5 087

**South Ukraine NPP**
- Electricity production for 8 months 2015 - 10.6 bln kWh (18.4% of the overall electricity production by SE “NNEGCG “Energoatom”)
- Number of employees - 6 877

**Zaporizhzhya NPP**
- Electricity production for 8 months 2015 - 24.7 bln kWh (42.8% of the overall electricity production by SE “NNEGCG “Energoatom”)
- Number of employees - 11 076

SE NNEGCG Energoatom covers over 56% of Ukraine’s demand for electricity
ELECTRICITY PRODUCTION IN UKRAINE

ELECTRICITY SUPPLY TO THE ENERGY MARKET OF UKRAINE
Ukrainian Priorities for the nearest future in nuclear area (up to 2025)

- Extending the lifetime of running power units
- Completeness and put into operation of the new electrical lines 750 kV from RNNP, KhNPP and ZNPP to central part of Ukraine (2016-17)
- Constructing two new power units on the Khmelnitsky NPP site
- Building and Operation of fuel fabrication plant
- Building the third hydropower unit of the Tashlyk Hydro Pumped Storage Power Plant at SU NPP site;
- Establishing a central spent nuclear fuel storage for Rivne, South Ukraine and Khmelnitsky NPP;
- Ensuring implementation of the Project on qualification of an alternative nuclear fuel supply source for Ukrainian NPPs
- Funding establishment of a state reserve of nuclear fuel and materials
- Construction of storage facility at «Vector» site in Chernobyl exclusion zone for long-term storage of the vitrified HLW produced after SNF reprocessing that will be sent back from Russia;
- To put into operation National Training Center for the Maintenance and Management Personnel on the base of Zaporizhzhya NPP (in 2016)
Construction of new nuclear generating capacities depends on:

- Macroeconomic indicators of development and forecast of electricity production/consumption

- Economically justifiable share of each generation type (thermal, nuclear, wind, solar and so on), taking account of estimated energy reserves and environmental impact mitigation solutions

- Plan of development of the Unified Energy System of Ukraine for the next decade (to be issued annually by the TSO and approved by the Cabinet of Ministers of Ukraine)
OPTIONS OF NUCLEAR POWER INDUSTRY DEVELOPMENT

Background:

Between **2030 and 2040**, the extended lifetime of 12 nuclear power units will expire resulting in the annual electricity generation reduction by **76 TW*h**

Between **2041 and 2055**, a further 3 nuclear power units will have their extended lifetime expired. As a result, the annual electricity generation will be further reduced by **21 TW*h**
Nowadays, according to the Energy Strategy of Ukraine in force, the total installed capacity of nuclear generation is expected to reach 18 GW by 2035.

New nuclear power units (except Kh-3, Kh-4) with a total capacity of 5 GW (including 3 GW of the replacing ones) should be put in operation over the period from 2027 to 2035.

To that end, it is necessary to:

- complete the land-inventory list (cadastre) of sites for construction of power units of new NPP and the power units replacing the capacities of NPPs in operation (expected to be completed in 2015);
- identify, by 2017, the type of nuclear installations, which will be deployed for new power units;
- take into consideration, when selecting the type of nuclear installations, the infrastructure available for building and operation of PWR-type reactors with the potential future construction of components of a partially-closed or closed nuclear fuel cycle;
- start, by 2018, front-end engineering design for construction of power units.
The nuclear energy system in Ukraine may look like in 2035

1. Lifetime extension of the acting NPP units of Ukraine for 20 years. Lifetime of 11 units (the installed capacity of each unit is 1 GW) is supposed to be extended. By 2035 total capacity of NPPs in operation will make up 18 GW.

2. Construction and commissioning of new units with total capacity of 5 GW by 2035 (according to the basic scenario of Ukrainian Energy Strategy).

3. Commencement of construction of new units to replace those to be decommissioned after 2035 (it is necessary to start construction of 12 GW of installed capacity).

4. Provision of Ukrainian NPPs with domestically mined uranium in the amount of 3000 t per year by 2035 that will allow to cover the demand of about 18 GW of the installed capacity of LWR.

5. Operation of fuel fabrication plant

6. Preparation to decommissioning of 10,88 GW of installed capacity in 2031-2039.

7. Operation of the dry spent nuclear fuel storage facility (DSNFSF) at Zaporizhzhya NPP and centralized spent nuclear fuel storage facility (CSNFSF). All SNF from running Ukrainian NPPs will be stored.

Nuclear share in total energy mix in 2035 will be nearly 50%
Types of the reactors which can be built and their capacity

- In the near-term (before 2035) Gen-III+ LWR are more likely to be selected for construction in Ukraine. Heavy water reactors are also considered to be built.
  - Possible LWR types: AES-2006, AP-1000, APR-1400
  - Possible HWR types: CANDU EC6.
- The following LWR and HWR designs may be selected for construction in 2035-2050: AES-2006, AP-1000, APR-1400, EPR-1600, CANDU EC6.
- Construction of fast reactors after 2050 may also be considered.

Assumed nuclear fuel cycle:
Open NFC will be used until SNF reprocessing issues are solved.
ARRANGING FOR ENGAGEMENT AND EFFECTIVE USE OF THE INTERNATIONAL TECHNICAL ASSISTANCE

EC

TACIS

- Establishing the solid radioactive waste treatment complexes – EUR 21.3 M (Program is being finalized)

INSC (Instrument for Nuclear Safety Cooperation)

- 14 projects under implementation (EUR 24 M)
- 2 projects valued at EUR 4.4 M, ready for implementation

SSM (Sweden)

Under the Technical Assistance Program for 2016-2017, preparatory activities are underway to launch the new National Project “Improvement of Safety-Related Nonconformity Management System”

IAEA

- Cooperation is underway under the Agreement between the Cabinet of Ministers of Ukraine and the Government of Sweden, dated 29.08.2007. The total volume of funding allocated for the projects amounts to SEK 30 million. To date, 3 projects are under implementation.

54 meetings were held under the Tacis and INSC projects and 7 meetings took place under the Projects with SSM during 8 months of 2015
Implementing the international programs on nuclear safety improvement of Ukraine NPP is an important area of the international cooperation.
International Cooperation

Our Company is involved in:

- **INPRO International Project on Innovative Nuclear Reactors and Fuel Cycles under the aegis of IAEA**;
- **the EUR group on development of requirements to new reactor installations**;
- **the international framework for nuclear energy cooperation (former Global Nuclear Energy Partnership GNEP)**;
- **World Nuclear Association WNA**;
- **World Association of Nuclear Operators (WANO) etc.**

We develop bi-lateral cooperation:

- **with AECL (Canada) in doing a joint assessment of technical and economic feasibility of deploying CANDU in Ukraine**;
- **successfully finalize a project on nuclear fuel qualification for Ukrainian NPPs in cooperation with Westinghouse**;
- **in recent years Energoatom’s partner group was extended to include Korea Electric Power Corporation (KEPCO, South Korea), PGE (Poland), CGNPC (China) and others.**
Key areas of international cooperation

- **Nuclear fuel management:**
  - nuclear fuel fabrication – cooperation with the Russian Federation (TVEL), Westinghouse;
  - spent fuel storage – cooperation with the Russian Federation (TVEL) and AREVA (for Westinghouse SNF);
  - construction of CSNFSF – cooperation with the USA (Holtec International).

**Design and research, scientific and technical support of NPP operation:**
- the Russian Federation (Hydropress, Kurchatov Institute), the Czech Republic (Nuclear Research Institute Rez, Skoda), Slovakia (Vuje);
Key areas of cooperation (cont.)

**NPP safety improvement:**

- cooperation with EU member-states in the framework of Tacis and INSC Programs funded by the European Commission;
- cooperation in the framework of the International program on nuclear safety that was funded by the US Government (was completed in 2006, except for the Ukrainian Nuclear Fuel Qualification Project);
- cooperation under the IAEA Technical cooperation program (including OSART missions. For the past 15 years Ukrainian NPPs hosted 8 OSART missions);
Key areas of cooperation

NPP safety improvement:

- cooperation in the framework of WANO (including peer reviews. For the past 15 years Ukrainian NPPs hosted 9 peer reviews, 30 WANO technical support missions);

- project on status assessment of the running Ukrainian NPPs for their compliance with the international standards and requirements for nuclear safety (performed by the IAEA experts, European Commission, Ukraine and independent experts from international organizations. Experts from 23 countries and international organizations participated in the assessment. Based on the results of 14 expert missions conclusions were made. They confirmed the compliance of the Ukrainian NPPs to the most requirements of the effective IAEA safety standards);

- cooperation with international group EUR.
Drivers and impediments for international cooperation

Factors that motivate cooperation, factors that could impede cooperation

Factors that motivate cooperation:
• need for technologies and components which are not available in Ukraine;
• need for application of the best international practices;
• need for cooperation for joint solution of the problems.

Factors that could impede cooperation:
• holders of the reactor technologies may be “overloaded” with commercial orders;
• potential influence of political and economical considerations on the application of technologies of other countries;
• negative experience in relations between countries (companies), which was previously acquired in other areas.
Possible criteria of supplier selection:

- experience in the use of this supplier’s technology;
- similarity of regulatory requirements;
- possibility to localize the equipment manufacturing in Ukraine and/or possibility of control (impact on) of security of supplies;
- possibility to get sufficient (at acceptable cost) scientific and technical support for the implemented technology;
- financial stability of the supplier.

In future the following key areas of international cooperation for Ukraine may appear:

- SF reprocessing and NFC closure;
- design and commissioning of the innovative (advanced in fuel application and safety) reactors;
- HLW management (disposal).
Role of Ukraine in the deployment of nuclear power plants supplied by foreign companies

Local services:

- uranium mining and U$_3$O$_8$ production;
- nuclear fuel fabrication;
- NPP design (based on the purchased reactor design);
- metal production for the major components of the reactor installation;
- manufacturing of the major equipment of the turbine unit;
- manufacturing of pumps, compressor equipment, valves and pipelines;
- I&C design and manufacturing;
- electrical equipment manufacturing (transformers, breakers, etc.);
- spent nuclear fuel storage;
- waste reprocessing;
- HLW disposal.
Role of Ukraine in the deployment of nuclear power plants supplied by foreign companies

Purchase of foreign services:

- Conversion services, uranium enrichment and reactor design.
- Manufacturing of the major equipment of the reactor installation (reactor pressure vessel, steam-generators).
- Manufacturing of the electrical generator for turbine unit
- Services related to spent nuclear fuel reprocessing.
Some examples of the international cooperation in the nuclear area of Ukraine
SE NNEGС “Energoatom” spares no efforts to diversify fuel supply sources to nuclear power units of Ukraine. This process was initiated back in 2000 by signing on June 5 the Executive Agreement between the Government of Ukraine and the Government of the USA regarding the Nuclear Fuel Qualification Project for Ukraine.

- The project was implemented in two stages
- **Stage I of the Project** (from 2005 to 2009) included trial operation of 6 lead test WFA assemblies at SU NPP unit 3 within four fuel campaigns
- **Stage II of the Project** (since March 2010) provided start of trial operation of a Reload Batch of 42 WFAs manufactured by Westinghouse
- In March 2008 the SE NNEGС “Energoatom” and Westinghouse Electric Sweden AB (Vasteras, Sweden) signed a contract for the supply of nuclear fuel to permit annual reload of 3 VVER-1000 power units
- Operation of these fuel assemblies started in 2011
- In 2012 and 2013 WFAs were not loaded into the cores of Ukrainian power units in view of refinement and improvement of the fuel assembly design undertaken by Westinghouse
2013 saw the start of supplies of component parts to the Russian Federation under the Contract with TVEL OJSC that are used in fabrication of nuclear fuel for Ukraine NPP.

In 2014, under the Fresh Fuel Fabrication Program, TVEL OJSC delivered five batches of component parts consisting of 228 top nozzles and 228 bottom nozzles.

In 2015, 343 TVSA (83%) out of 481 TVSA to be delivered to Ukraine NPP, will be produced using top and bottom nozzles made in Ukraine.

In 2016, 400 top nozzles and 400 x bottom nozzles shall be manufactured.
First Stage – a License Agreement on technology transfer was signed with TVEL OJSC in 2008

Second Stage – SE NNEGC Energoatom mastered the fabrication of component parts (*top and bottom nozzles*) for VVER-1000 TVS-A, using the facilities of SE Atomenergomash

Final stage – Qualification testing of a test batch of component parts was carried out in 2012, followed by the start of the full-scale production

The total volume of investments in establishing the production of TVSA component parts at the Machine and Repair Works of SE AtomEnergoMash approximates UAH 70.0 M including:

- around UAH 17.0 M – cost of the TVEL OJSC’s technology, including the technology transfer and assimilation
- around UAH 38.0 M – costs of major equipment procurements
ESTABLISHMENT OF THE CENTRAL SPENT FUEL STORAGE FACILITY FOR VVER REACTORS OF UKRAINIAN NPPS (CSFSF)

Project Objective:
Improvement of spent nuclear fuel (SNF) management system of Ukrainian NPPs towards enhancing energy independence of Ukraine by ceasing the SNF transfer to the Russian Federation

Project completion term – **2050**
incl. start-up complex completion – **in 2017**
All required infrastructure and **94** SNF storage systems will be put in place as a part of the start-up complex on CSFSF site.

- The start-up complex equipment will be supplied under the contracts with the technology owner – **Holtec International**
- The CSFSF is designed under the contract with Ukrainian designer – Kyiv Research and Design “Energoprojekt” Institute

Location: construction of the central spent fuel storage facility for VVER reactors of Ukrainian NPPs is carried out in the Chernobyl Exclusion Zone (Kyiv oblast) in accordance with Law No. 4384 of Ukraine on CSFSF (dated 09.02.2012)

**Design storage capacity:**
- ✔️ **12010** SFA of VVER-1000;
- ✔️ **4519** SFA of VVER-440

**Storage capacity of CSFSF start-up complex:**
- ✔️ **2511** SFA of VVER-1000;
- ✔️ **1105** SFA of VVER-440

It is expected that the CSFSF will be filled up to design capacity in **45-50 years**
Design lifetime – **not less than 100 years**
Objective of the Project:
Training of all category personnel to be employed in construction and operation of new nuclear power capacities

Total approved costs of construction – UAH 512.5 M

Project on “Establishment of the National Training Center for Maintenance and Management Personnel of SE NNEGC Energoatom at ZNPP” was launched in 2009 under the Program on International Technical Assistance between the European Union and Ukraine.

Two independent projects were united forming integral parts of this Project. These are:

1. Establishment of the National Training Center for Maintenance Personnel of SE NNEGC Energoatom (NTCMP)
2. Establishment of the National Training Center for Management of SE NNEGC Energoatom (NTCM)
PILOT COURSE AT VVER-1000 REACTOR SIMULATOR

Removal - installation of an upper block of VVER-1000
Maintenance, adjustment and testing of a refueling machine mast (MPS-1000)
A Unique Training Centre for Nuclear Personnel is under completion in Ukraine

_Energodar, October 2015_

• In partnership with the European Union, SE NNEGC Energoatom completes the construction of the National Training Centre, which boasts a first of its kind full scope simulator of a VVER 1000 reactor unit.

• Co-financed between the European Union and the Ukrainian Government, Energoatom’s National Training Centre is a state-of-the-art nuclear power unit maintenance training facility, located at the site of the Zaporozhye Nuclear Power Pant. When opened for full operation in 2016, the facility will deliver maintenance training based on best international practice to maintenance personnel from the company’s fleet of VVER nuclear power units, which are located at four nuclear power plants across Ukraine.
The training centre’s first of a kind simulator of a nuclear power unit will facilitate training and qualification of maintenance staff utilising a variety of full scope equipment models, in simulated environmental conditions, thus ensuring maintenance actions to be carried out on installed operational equipment, and are being implemented to the highest standards of safety for both the maintenance personnel and equipment to be maintained. In addition to maintenance training, the project has established a management training system within NNEGC Energoatom. The management training, which is also based on international best practice, emulates management principles and practices employed by international nuclear operators that are considered to be best in class. The combined results of these two key elements will provide Ukraine’s nuclear operator with the means to support the safe implementation of the country’s energy strategy regarding electricity generation from nuclear power. The project, which was initially launched by the Ukrainian Government in the late 1990’s, but suffered some seven years of interruption, was finally re-launched in 2007 based on a common agreement between the European Union and the Ukrainian Government. The European Union contribution to the project, was €14M from the "Instrument for Nuclear Safety Cooperation".
Thank you for your attention!