“Drivers and Impediments Regional Cooperation on the Way to Sustainable Nuclear Energy Systems”
There are 4 NPPs in operation in Ukraine. These nuclear power plants comprise 15 units with total capacity 13,835 GW.

- **Zaporizhzhya NPP** – 6 units with VVER-1000, total capacity 6 GW;
- **Rivne NPP** – 4 units with 2 VVER-440 and 2 VVER-1000, total capacity 2,835 GW;
- **Khmelnitsky NPP** – 2 units with VVER-1000, total capacity 2 GW;
- **South-Ukraine NPP** – 3 units with VVER-1000, total capacity 3 GW.
1. Current status of nuclear power program in Ukraine

Nuclear power plants

- For the past 5 years NPP share in total electricity generation in Ukraine has made up 47-48%. Average load factor of NPP units in 2010-2011 made up about 75%.

- In 2010 lifetime of the units 1-2 at Rivne NPP with total capacity 0.835 GW was extended for 20 years beyond their design 30-year lifetime.

- In 2012-2019 design lifetime of 10 units with total capacity 10 GW will be expired. In 2025 design lifetime of one more unit (1GW) will be expired.

- Design work is being implemented in the framework of construction (completion) of units 3 and 4 at Khmelnitska NPP (construction was suspended after Chernobyl accident). The Law on Construction of Units 3 and 4 at Khmelnitsky NPP is to be adopted by the end of 2012. Commissioning of unit 3 is scheduled in 2018, unit 4 - in 2020.
1. Current status of nuclear power program in Ukraine

FRONT END

- There are uranium deposits and mining capacities in Ukraine. The extracted uranium is used for fuel fabrication for the Ukrainian NPPs. The local uranium covers about 30% of nuclear fuel demand for Ukrainian NPPs (about 800 t per year).

- A decision was made to build a nuclear fuel fabrication plant. Its commissioning is scheduled in two stages. First stage in 2012-2015 and the second one – in 2016-2020. Design capacity of the plant will make up 800 fuel assemblies per year.
1. Current status of nuclear power program in Ukraine

**BACK END**

- Spent nuclear fuel of Rivne NPP, South-Ukraine NPP and Khmelnitska NPP is sent for reprocessing to Russian Federation. Reprocessing waste will be sent back to Ukraine.

- Spent nuclear fuel of Zaporizhzhya NPP is being stored in dry SNF storage facility at the site of Zaporizhzhya NPP.
A centralized SNF storage facility for spent nuclear fuel of VVER type reactors is under construction in the Chernobyl exclusion zone. The commissioning of CSNFSF is scheduled in 2015. (A resolution # 131-r dated 4.02.09 approved the feasibility study on investments and in 2012 a Law on nuclear installation siting and (construction) deployment was adopted). The design capacity of the CSNFSF is 16529 spent nuclear fuel assemblies, including 12010 spent nuclear fuel assemblies of VVER-1000 and 4519 spent nuclear fuel assemblies of VVER-440).

Waste management. Waste treatment (evaporation of liquid radwaste, sorting and compaction of solid radwaste) is performed on-site. Facilities on deep reprocessing of radwaste is under deployment. In future radwaste may be transported to the enterprise “Vector” which is specialized in waste management.
2. Driving forces for expanding nuclear power program

2.1. Driving forces for expanding nuclear power program in Ukraine are listed below:

- need in significant base-load generating capacities for industrial development;
- availability of domestic uranium deposits;
- availability of infrastructure to support NPP operation, human resources, personnel training system, NPP operation experience;
- keeping CO$_2$ emissions at low level.
2.2. Impediments that may impact expanding nuclear power program in Ukraine are listed below:

- public acceptance taking into account Chernobyl accident;
- possible social problems during site selection for new NPP;
- unavailability of proven financing sources for new NPP construction.
3. How the nuclear energy system in your country may look like in 2030 and in 2050

3.1.1 Nuclear energy system in 2030

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 2030 total capacity of NPPs in operation will make up 13.8 GW.

2. Construction and commissioning of new units with total capacity of 5 GW by 2030 (according to the basic scenario and considering the completion of units 3 and 4 at Khmelnitska NPP).

3. Commencement of construction of new units to replace those to be decommissioned after 2030 (it is necessary to start construction of 12 GW of installed capacity).
3.1.1 Nuclear energy system in 2030

4. Provision of Ukrainian NPPs with domestically mined uranium in the amount of 3000 t per year by 2030 that will allow to cover the demand of about 19 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.

*Total installed capacity of NPPs in 2030 may be about 19 GW, nuclear share in total energy mix – 47-48%*
3.1.2 Nuclear energy system in 2050

1. Operation follow-up of the NPP units that were built before 2030. Total installed capacity – 8 GW (Zap NPP-6, KhNPP-2,3,4, RNPP-4, units at new sites – 3 GW).

2. Construction and commissioning of new units from 2030 to 2040 to replace those ones under decommissioning with total capacity 11 GW (RNPP-1-3, SUNPP-1-3, Zap NPP-1-5, KhNPP-1).

3. Construction and commissioning of new units with installed capacity of 3 GW after 2030 to meet the growing demand for electricity (criterion – about 50% of electricity output in energy mix).

4. Decommissioning of 12 units (10.88 GW) in 2031-2039
   - 2031-2032 – decommissioning of units RNPP-1 and RNPP-2 (total capacity 880 MW);
   - 2033-2039 – decommissioning of 10 units with VVER-1000 (total capacity 10 GW).
3.1.2 Nuclear energy system in 2050

5. Provision of Ukrainian NPPs with domestically mined uranium in the amount of 5000 t per year by 2050 that will allow to cover the demand of about 22 GW of the installed capacity of LWR.

6. Operation of fuel fabrication plant.

7. Operation of CSNFSF and DSNFSF at Zap NPP.

*Total installed capacity of NPPs in 2050 may be about 22 GW, nuclear share in total energy mix - 46-49%*
3.2 (1) Types of the reactors to be built and their capacity

- In the near-term (before 2030) 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.
  
  Possible HWR types: CANDU EC6.

- The following LWR and HWR designs may be selected for construction in 2030-2050: AES-2006, AP-1000, APR-1400, EPR-1600, CANDU EC6.

- Construction of fast reactors before 2050 may also be considered.
3.2 (2) Assumed nuclear fuel cycle (e.g., open or closed)

- Open NFC will be used until SNF reprocessing issues are solved.

3.2 (3) Local NFC services and foreign suppliers:

Local NFC services:
- uranium mining and U$_3$O$_8$ production, pellets sintering, nuclear fuel fabrication, spent nuclear fuel storage, HLW disposal;

Foreign suppliers of NFC services:
- conversion services, uranium enrichment, design and manufacturing of reactors, spent nuclear fuel reprocessing.
3.3 Selection criteria for technologies and services are listed below:

- proven and mature technology;
- compliance with European utility requirements (EUR);
- economic attractiveness;
- possibility of maximum localization for equipment manufacturing;
- maximum compliance of new technology with the existing infrastructure;
- diversification (fuel, applied technologies), security of electricity supply.
4. Role of Ukraine in the deployment of nuclear power plants supplied by foreign companies

Local services:

- uranium mining and $U_3O_8$ 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.
4. 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.
5. Vision of the NFC back-end services

Nowadays Ukraine performs:

- spent nuclear fuel transportation to Russia for reprocessing;
- "deferred decision" - long-term SF storage (at Zap NPP) with subsequent decision on application, reprocessing, disposal.
- transportation of SNF to Russia and HLW return is legally adjusted

The following activities also provide for:

- construction of a central SNF storage facility at Chernobyl exclusion zone in 2014, cease of SNF transportation to Russia (deferred decision);
- construction of storage facility at «Vector» site for long-term storage of the vitrified HLW produced after SNF reprocessing that will be sent back from Russia;
- development of strategy and technologies related to safe and economically viable management of SNF and its processing products.
6. Concept of sustainable nuclear energy system

*Sustainable energy system means a system that meets the current demands in energy taking into account that future generations will also be able to meet their demands.*
6.1 Assessment of sustainability of national nuclear energy system

- In 2006-2008 Ukraine conducted the national study of the innovative nuclear energy system for the period till 2030 under the INPRO Program. A comparative assessment of various options of NFC was performed.

- In 2009-2010 Ukraine participated in GAINS project on the assessment of global NFC architecture. NFC sustainability was considered as one of the important conditions for nuclear power development.

- At present, the Project “Strategic Nuclear Energy Planning of Ukraine in the Framework of INPRO” is being implemented in collaboration with the IAEA. The project envisages the assessment of various options of NFC configurations for their «sustainability» based on the methodology described in TECDOC-1575.
6.2 Priorities of Ukraine related to the sustainability of nuclear energy system

- SAFETY
- INFRASTRUCTURE
- ECONOMICAL ISSUES
- RADIOACTIVE WASTE MANAGEMENT
- ENVIRONMENT
6.3 National requirements/indicators related to the sustainability of nuclear energy system

Ukrainian regulations do not contain direct requirements and indicators related to the sustainability. There is a legal and regulatory framework on nuclear and radiation safety, environmental and human health protection in Ukraine.
7. Vision of energy independence and security of supply

7.1 Vision of energy independence and security of supply for Ukraine

7.1.1 Vision of energy independence for Ukraine

- Generating capacities secure internal demand of Ukraine for electricity.
- Availability and mining of domestic resources sufficient to cover the needs of electricity generating facilities.
- The highest level of localization of facilities for construction and operation of generating capacities.
- Dependency on foreign companies in some issues is clearly identified, work on minimizing such dependency is being performed.
- In cases when dependency on other countries is inevitable, supply sources are diversified (or may be diversified).
- National scientific and technical infrastructure has been set up for analyzing and planning the country’s activities (including development or acquisition of technologies) to solve the above-mentioned problems.
7.1.2 Vision of security of supply for Ukraine

- Manufacturing of components for power industry, localized in Ukraine, provided with resources and orders with reliable performance, internal products have sufficient priority

- Supplies from foreign suppliers are diversified (or may be diversified)

- In case of supplies of technologies/components from foreign suppliers, there is a well-established cooperation with foreign partners (with involvement of national scientific and technical infrastructure, if necessary)
7.2 Factors that contribute to achieving Energy independence and security of supply and those that may impede such achievement (for nuclear energy)

Contribution to achieving Energy independence and security of supply
- availability of domestic uranium deposits, technologies and infrastructure for uranium mining;
- availability of infrastructure for NPP construction and operation, high level of localization and prospects of its increase
- deployment of nuclear fuel fabrication in Ukraine
- availability and prospects of waste management infrastructure development
- availability and prospects of spent nuclear fuel storage infrastructure development

Obstacles in achieving Energy independence and security of supply
- foreign suppliers dependency in reactor technologies, nuclear fuel fabrication and SF reprocessing technologies
7.3 Energy independence and Security of supply considerations and cooperation/collaboration with other countries

In case of technology supplies from foreign suppliers, a mutually beneficial cooperation with foreign partners should be established.

Cooperation with the involvement of third parties and establishment of international organizations are preferable.
8. Cooperation with other countries on energy issues

8.1 Experience of Ukraine in cooperation with other countries in the projects related to energy

Key areas of cooperation

- Nuclear fuel management:
  - nuclear fuel fabrication - cooperation with the Russian Federation (TVEL), Westinghouse;
  - spent fuel storage - cooperation with the Russian Federation (TVEL);
  - construction of CSNFSF - cooperation with the USA (Holtec International).
Key areas of cooperation

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);

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.
8.2 Prospects of cooperation in nuclear issues with neighboring countries

Besides above-mentioned areas of cooperation the following issues are also considered to be top priorities:

- uranium enrichment – via its State Company «Nuclear Fuel» Ukraine has 10% of shares in the International center on uranium enrichment in Angarsk;
- SF reprocessing – possible cooperation with Russia and other countries, technology holders;
- construction of the nuclear fuel fabrication plant in Ukraine – cooperation with Russia;
- reactor and nuclear power plant design – cooperation with the countries and individual companies which develop reactor technologies (AREVA, Westinghouse, KEPCO and etc.);
- manufacturing of reactor components – cooperation with countries where such manufacturing is possible;
- cooperation in the framework of bilateral agreements between Energoatom and foreign companies (Iberdrola, AREVA, Westinghouse, ROSENERGOATOM and etc.)
9. Drivers and impediments for cooperation

9.1 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.
9.2 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 may appear:

- SF reprocessing and NFC closure;
- design and commissioning of the innovative (advanced in fuel application and safety) reactors;
- HLW management (disposal).
Thank you for your attention