A Ukrainian Roadmap for Small Modular Reactors: Current Activities and Future Plans

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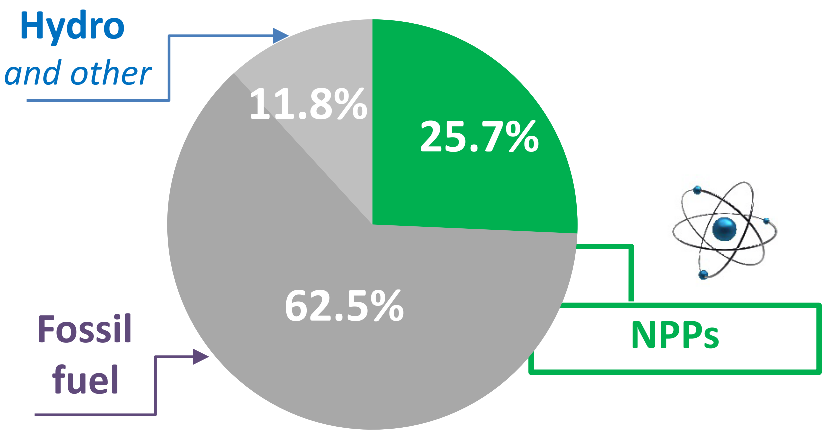
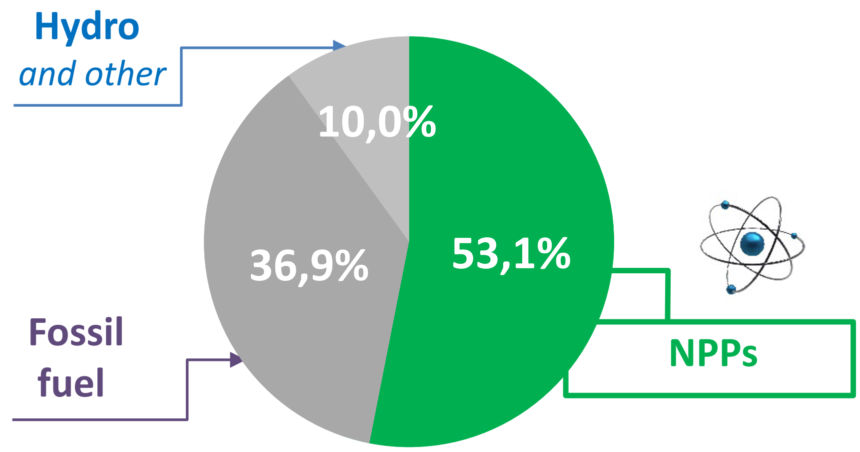
Ukraine’s Energy Mix in 2018

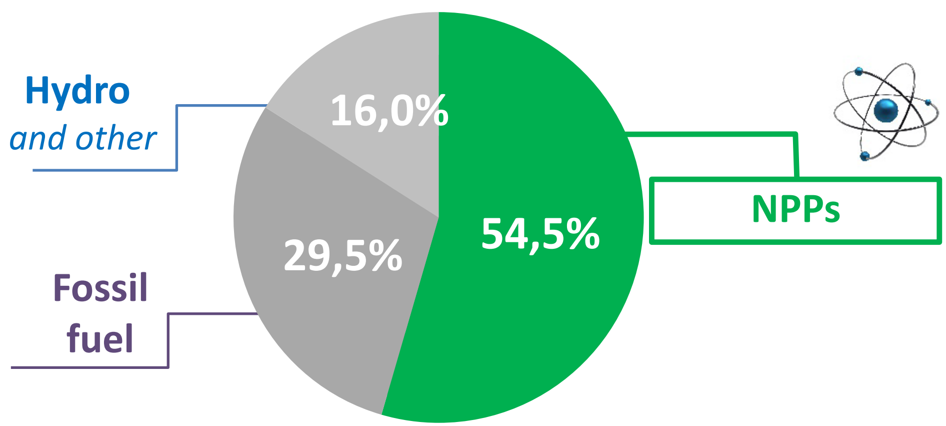
The structure of generating capacities



The structure of electricity production



The structure of electricity output to the energy market of Ukraine



Ukraine’s Nuclear Energy Generation

RNPP - 2 835 MW

ZNPP – 6 000 MW

KhNPP – 2 000 MW

Total installed electrical capacity of generating facilities of SE NNEGC Energoatom

14 148,5 MW (13,835 MW - nuclear)

SOUTH UKRAINE POWER COMPLEX
3 313,5 MW

Tashlyk PSP - 302 MW

SUNPP – 3 000 MW

Oleksandrivska HPP - 11,5 MW

Nuclear Energy Policy in Ukraine

In August 2017 a new Energy Strategy for the period until 2035 was approved by the Government of Ukraine. It confirms **further development of nuclear power** in the country by keeping its share in electricity generation at least at 50%. To achieve this goal the following steps have been outlined:

- **By 2020:**
  - Implementation of safety enhancement and NPP efficiency improvement programs (target load factor - 85%)
  - Beginning of Khmelnitsky NPP-3 construction;
  - Decisions and action plans on the replacement of NPP capacities to be decommissioned after 2030;
  - Selection of reactor technologies for construction of new power units to replace NPP capacities to be decommissioned after 2030;
  - Development and approval of a long-term nuclear energy development programme

Nuclear Energy Policy in Ukraine (cont'd)

- **By 2025:**
  - Commissioning of NPP with installed capacity of 1 GW (KhNPP, unit 3)
  - Design and construction of NPPs in accordance with the long-term nuclear energy development programme, including potential deployment of SMRs at the sites of NPPs to be decommissioned and operating TPP sites (to generate electricity and supply heat to big cities).
- **By 2035:**
  - Decisions on lifetime extension or decommissioning of NPPs with expired lifetime;
  - Construction and commissioning of NPPs in accordance with the long-term nuclear energy development programme (for replacement of installed capacities of NPP to be decommissioned after 2030);
  - Preparation of infrastructure for decommissioning of NPP power units

Ukrainian Nuclear Power Development Roadmap

NPP operation and electricity generation dynamics with preserved production at the achieved level (installed capacity - 15 GW) till 2040

Units \ Years	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
RNPP-1	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42																									
RNPP-2	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415	0,415																								
RNPP-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
RNPP-4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
SUNPP-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																						
SUNPP-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
SUNPP-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
ZNPP-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
ZNPP-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
ZNPP-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																			
ZNPP-4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
ZNPP-5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
ZNPP-6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										
KhNPP-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																	
KhNPP-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
KhNPP-3								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
KhNPP-4															1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-1																		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-2																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-3																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-4																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-5																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-6																						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-7																						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-8																							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-9																								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-10																								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
New Unit-11																														1	1	1	1	1	1	1	1	1	1
New Unit-12																																							1
New Unit-13																																							1

Design
Operation
Extended operation
Decommissioning

Lifetime Extension of operating NPPs

Lifetime extended
(9 power units)

RNPP - №1
VVER-440/213
License obtained on 10.12.2010

RNPP - №2
VVER-440/213
License obtained on 10.12.2010

RNPP- №3
VVER-1000/320
License obtained on 17.07.2018

SUNPP - №1
VVER-1000/302
License obtained on 02.12.2013

SUNPP - №2
VVER-1000/338
License obtained on 09.12.2015

ZNPP - №1
VVER-1000/320
License obtained on 14.09.2016

ZNPP - №2
VVER-1000/320
License obtained on 03.10.2016

ZNPP - №3
VVER-1000/320
License obtained on 03.11.2017

ZNPP - №4
VVER-1000/320
License obtained on 12.10.2018

Work is on-going
(3 power units)

KhNPP - №1
VVER-1000/320
25.11.2018 it was shut down for outage

SUNPP - №3
VVER-1000/320
Design lifetime will end on February 2020

ZNPP - №5
VVER-1000/320
Design lifetime will end on May 2020

Lifetime has not ended
Lifetime will end after 2020
(3 power units)

ZNPP - №6
VVER-1000/320
(October 2026)

RNPP - №4
VVER-1000/320
(June 2035)

KhNPP - №2
VVER-1000/320
(September 2035)

Drivers for SMR Deployment in Ukraine

- ***Anticipated competitive cost of electricity produced by SMR;***
- ***Anticipated lower cost of SMR projects compared to large nuclear reactors;***
- ***The economy of scale due to the mass fabrication of modules;***
- ***SMR construction period is significantly less than for large nuclear reactors;***
- ***Modular construction provides for gradual capacity increase;***
- ***NPP deign can have flexible power configuration;***
- ***Anticipated load-follow capabilities provided by SMR;***
- ***The prospect of using SMR for combined heat and electricity generation;***
- ***Simplified design, passive safety systems, long design lifetime;***
- ***SMR units can be located closer to consumers than large nuclear reactors;***
- ***Possibility to use the existing energy infrastructure, including that of NPP units under decommissioning;***
- ***Significant localization opportunities.***

Deployment of SMR-160 in Ukraine

In late 2016 Company's President Yuriy Nedashkovskyi became a member of the Holtec Advisory Council for SMR-160 Small Modular Reactors

Priority Action Plan was approved In late February 2018, providing for replacement of existing nuclear power generating capacities with power units equipped with Holtec SMR-160

Memorandum of Understanding for Cooperation in the Field of Use of SMR-160 in Ukraine was signed with Holtec International on 28 February 2018

On 10th June 2019 Holtec, Energoatom and SSTC NRS entered into a Trilateral Consortium Partnership.

HOLTEC INTERNATIONAL

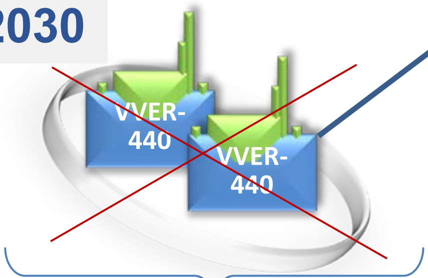
Define the key steps to be made in order to make an informed decision on the potential for introduction of the SMR-160 technology in Ukraine

6 SMR-160 units

To replace

RNPP

after 2030



to be decommissioned

2 power units

Focus Areas of the "Ukrainian Module" Consortium Partnership

- Analysis of regulatory documentation used in the development of SMR-160 power unit concept design.
- Analysis of the concept design of an NPP with SMR-160 power units.
- Development of input data needed for a Feasibility Study.
- Assessment of the SMR-160 design for its compliance with general and technical criteria using IAEA methodology for reactor technology assessment.
- Preparation of documents to support decision-making at the national level regarding deployment of SMR-160 reactor technology in Ukraine.

Current Main Focus Area:

The current national licensing and regulatory framework is applicable only to the reactor technologies existing in Ukraine, meaning VVER-type reactors, and in the present-day form cannot be used for other foreign designs of advanced reactor technologies, including SMRs.

Holtec Internationals Engineering Complex and manufacturing subdivision in Ukraine

1. To create a Consortium to facilitate the introduction of SMR-160 in Ukraine

2. Holtec Ukraine will build a manufacturing plant that will emulate Holtec's Camden Facility. Holtec Ukraine will serve to provide manufacturing opportunities to Ukraine's other manufacturers, such as suppliers of steam turbines, generators, pumps and valves, making Ukraine a vital part of the SMR-160 supply chain.

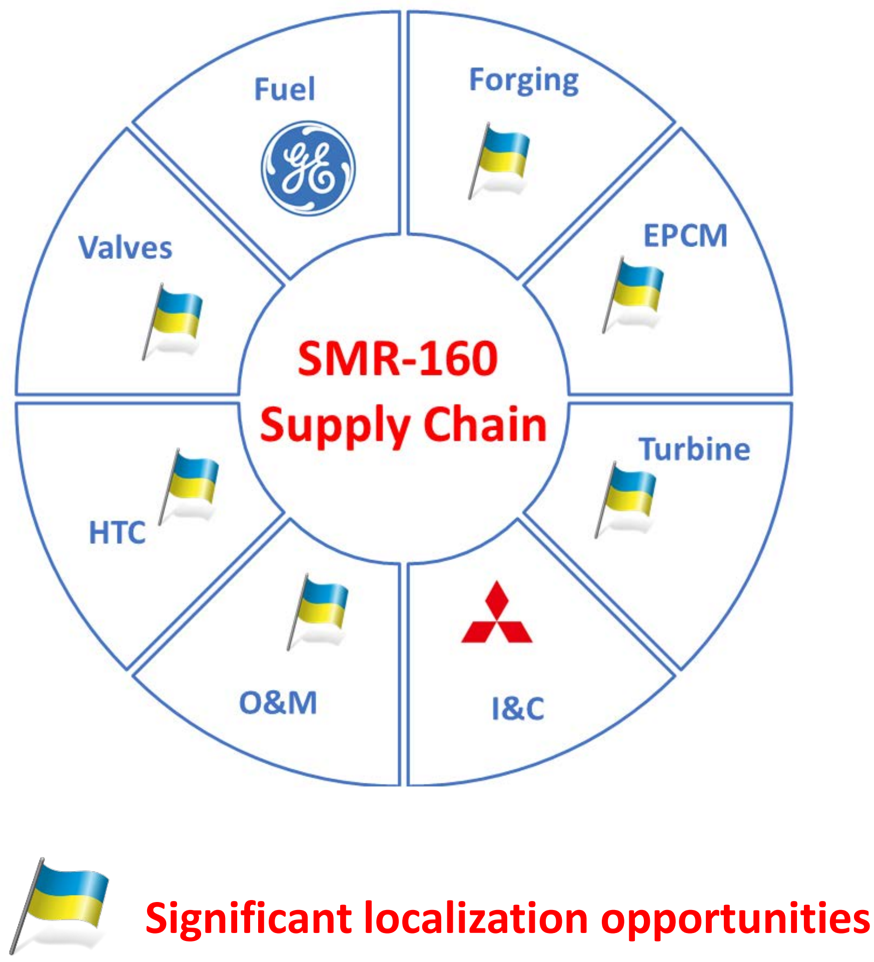
3. To enter international markets

Ukraine as a Hub for the Emerging Small Modular Reactor Industry

Ukraine has a well regarded nuclear energy program with a well trained nuclear work force.

The country can adopt Holtec's walk away safe small modular reactor SMR-160, each of which would power 400,000 Ukrainian homes.

SMR-160 will meet Ukraine's domestic needs for clean energy and give Ukraine a valuable long-term export opportunity.



Ukraine's User Technical Requirements for SMRs: Safety Requirements

- CDF must not exceed 10-5 per year, while striving to not exceed 10-6 per year.
- LERF must not exceed 10-6 per year, while striving to not exceed 10-7 per year.

Multi-modules PSA should be performed to demonstrate that all shared features don't lead to unacceptable effects.

SMR design shall assure that severe accident in one module shall not propagate to other modules.

SMR design should use the passive safety systems only based on gravitation and natural circulation.

Application of defence-in-depth concept to be applied with account of graded approach.

Security requirements for the most part will be the same as for large scale NPPs. Security concerns related to IT and I&C systems and cyber security.

Ukraine’s User Technical Requirements for SMRs: Performance Requirements

Capacity factor – more than 90%.

Refuelling cycle – 18-24 months or more.

LCOE should be lower than from coal plant with cleanup system.

Design operating lifetime – minimum 60.

SMR design must be capable to operate in cogeneration mode.

SMR design must provide better maneuverability and load following capabilities.

Ukraine’s User Technical Requirements for SMRs: Plant design requirements

NPP should be designed in accordance with international requirements by IAEA, WENRA, EUR.

SMR designs are expected to be located underground (at least partially).

SMR design should be licensable in vendor’s country or any other customer’s country.

Construction time from the 1st concrete until commercial operation – limited to 36 months.

SMR design should have an integrated nuclear steam supply system with no large bore pipelines eliminating LOCA accident.

EPZs should be scalable for SMRs with due account of source term, fission product release and doses.

Thank you for your attention!