Sustainability of Nuclear Energy System in Romania

View on the Resources Availability Aspects considering the INPRO Methodology Approach

C. A. Margeanu
RATEN-ICN Pitesti, ROMANIA

26 - 29 August 2014, Vienna
8th INPRO Dialogue Forum
National legal framework for Energy sector


Main objective: “...to satisfy the energy needs on short, intermediate and long term, with costs as low as possible, adequate to a modern market economy and a civilized life standard, in conditions of quality, supply security and with respect of the sustainable development principles.”

Strategic objectives: Security of energy; Sustainable development; Competitiveness

Uranium resources:
“Existing and exploitable Uranium resources assure natural U required for operation of Cernavoda NPP Units 1 and 2 till 2017... In order to assure the necessary of Uranium for the nuclear fuel used by the already operating Cernavoda Units 1 and 2 and for the perspective operation of Units 3 and 4, two directions are mandatory to be followed: assuming the risks for opening new national capacities for U production and assuring the legal framework and participation to international U ore concessions for exploitation or to import of U ore or technical concentrates.”
National Energy Strategy updating attempts:


Uranium resources:
“The main directions in Romania’s Energy Strategy, in line with the ones of European Union Energy Policy, are as follows: .... diversification of the U supply sources by combining rational exploitation of the national U resources with the U import and/or international U ore concessions for exploitation.”


Uranium resources:
“- promotion of new technologies and using of modern equipment for existing U ore exploitations; - opening of new U ore exploitations; - modernization and upgrading of the existing U refining capacities; - National Budget sustaining funds for: U technical concentrates exploitation, preparation and using; increasing of geological knowledge on identified U resources; evaluation and using of U resources from poor ore dumps and decantation lakes; partnerships for concession of external U ores to be further explored and exploited.”

“Energy must play an essential role in Romania’s economical and social development... Energy policy is based on the development of infrastructure and competitiveness.”

Some of the strategic objectives:
- **Security of energy**: “Ensure the security for energy critical infrastructure, storage capabilities, including nuclear facilities”
- **Energy efficiency and environment protection**: “Promotion of the clean technologies... Implementing the technical solution for Cernavoda NPP SNF final disposal”
- **Encouraging the investments**: “Upgrading and increasing U refining capabilities; Partnership on external markets for concession of U ores to be further explored and exploited”

**Priority projects**: Reiterate the offer for construction of Cernavoda NPP Units 3 and 4; Heavy water production at competitive prices; Stimulation of R&D in nuclear energy field and technology transfer of GenIII – GenIV reactors.
Nuclear Energy national legal framework

**Background** - Romanian Nuclear Programme started in 1950

“National Strategy for the Development of the Nuclear Field in Romania and the Plan of Action for the implementation of this Strategy“ – Government Decision no. 1259 /2002  
NECESSARY TO BE UPDATED

**National Nuclear Plan** : “In 2025-2050 Romanian NPPs must contribute with about 40% to the total national electricity production in cost competitive conditions and assuring nuclear safety at the international standard requirements.”


“Capitalization of national U resources by development of extraction, U ore preparation and U technical concentrates refining”

SWOT analysis for Uranium:

- **Strengths**: initiation of the projects for opening new U ore exploitations and construction of U preparation/refining capacities; using of U assures a low cost energy generation

- **Weaknesses**: difficult extraction conditions; potential risks on the miners health and security; low U content in the ore; great transport distances from U exploitations to preparation capacities; using of old technologies and outdated equipment in U preparation capacities

- **Opportunities**: increasing internal demand for U technical concentrates; assuring national energy security of supply; considering of other U sources and using advanced technologies for their processing

- **Threats**: constraints on the budgetary funds allocated for the investment objectives; lack of financing for environmental protection investments.

**Priority objectives**: efficient exploitation of Crucea-Botusana U ore; building of a new capacity for U ore processing, TG Plant Feldioara; R&D and operation of an installation for processing of the mining waste product from dumps and decantation lakes; building of a new capacity for U concentrates refining, YC Plant Feldioara; opening a new U ore exploitation in Oriental Carpathians.
Romania’s current “Once-Through” Nuclear Fuel Cycle

- **Indigenous Uranium Ore**
- **Uranium Mining and Milling**
- **Chemical Conversion and Purification**
- **“Feldioara” UO2 Powder Plant**
- **Nuclear Fuel Plant “Pitesti”**
- **NU-37 CANDU® Nuclear Fuel**
- **2 CANDU® 6 Reactors in operation**
- **Cernavodă NPP**
- **Disposal**
  - NU-37 Interim Storage
  - NU-37 Spent Nuclear Fuel
  - Maxtor Technology (50 years)
  - Reactor Cooling Bay (6 years)
- **Interim Storage for CANDU® Spent Fuel (DICA)**

**Uranium National Company S.A.**

**“Nuclearelectrica” National Company – SNN S.A.**
Uranium National Company

No Uranium market in Romania.

Uranium National Company (CNU) is the one and only supplier of UO$_2$ powder used as raw material for nuclear fuel fabrication.

Suceava Subsidiary, Crucea and Botusana mines, NE of Romania – active exploitation of U ore.

Feldioara Subsidiary – processing/preparation and refining of U technical concentrates

Department for Energy priority: opening of a new U ore exploitation, Tulghes-Grinties mines, NE of Romania
- estimated investment costs: 90 mil. euro
- time to complete the investment: 108 month
- estimated production: 124 000 tons U/year

Only 10% of the investment costs could be financed by CNU, for the rest the authorities are looking for funds – delegate Minister Nita declaration for The POWER newspaper, Jan. 2014
Considerations on the Romanian NES actual status*
- Once-Through Nuclear Fuel Cycle without reprocessing
- 2 PHWR reactors already operating at high performance parameters; commercial operation from: Dec 1996 – U1, Sept 2007 – U2
- Crucea-Botusana mines, Uranium National Company
- UO₂ Powder Plant Feldioara for U ore processing composed by 2 modules:
  - R Plant for U preparation (milling and concentration): 300 t U(U₃O₈)/y nominal capacity
  - E Plant for U refining and conversion: 300 t U(UO₂)/y nominal capacity
- Nuclear Fuel Plant Pitesti: 110 t U/y production capacity
- ROMAG PROD Heavy Water Plant : 360 t/y design capacity

Considerations for the analysis of Romanian NES sustainability:

- Time horizon for NES sustainability: 2050
- Maintaining in operation the existing nuclear capacities (2 PHWR reactors, CANDU type, 700 MWe each) and life extension for U1 to 40 years (CANDU reactor life time = 30 years)
- Commissioning of other 2 PHWR reactors, CANDU type, 720 MWe each, on the same site with the previous ones (Cernavoda NPP, SE of Romania) after 2030 (U3-2032; U4-2035)
- New U ore exploitation, Tulghes-Grinties mines
- New modules in Feldioara for U ore milling/processing (TG Plant) and U concentrates refining/conversion (YC Plant), to replace existing R and E modules
- Upgrading Nuclear Fuel Plant capacity of production to sustain operation of existing and new CANDU reactors
- No reprocessing for Spent Fuel; No enrichment
Sustainability of Nuclear Energy System in Romania

Resources Availability considering INPRO Methodology

**UR1: Consistency with resource availability**

**CR1.1 fissile/fertile material**

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>PHWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross electric power</td>
<td>700 MW</td>
</tr>
<tr>
<td>Net electric power</td>
<td>665 MW</td>
</tr>
<tr>
<td>Capacity factor</td>
<td>95%</td>
</tr>
<tr>
<td>Fuel burn-up</td>
<td>7.5 MWd/kgU</td>
</tr>
<tr>
<td>Life time</td>
<td>30 y</td>
</tr>
<tr>
<td>U consumption</td>
<td>90-100 tU/y</td>
</tr>
</tbody>
</table>

![Graph showing uranium needs from 2014 to 2050](image)
Nuclear Energy System

Considerations for the analysis of Romanian NES sustainability:

Uranium Ore Production in 1997-2006

Uranium domestic resources ** [USD/kgU]

<table>
<thead>
<tr>
<th>Identified</th>
<th>Reasonable assured</th>
<th>5260</th>
</tr>
</thead>
<tbody>
<tr>
<td>inferred</td>
<td>7570</td>
<td></td>
</tr>
<tr>
<td>Undiscovered</td>
<td>Prognosticated</td>
<td>12000</td>
</tr>
<tr>
<td>Speculative</td>
<td>16000</td>
<td></td>
</tr>
</tbody>
</table>

** media news based on unofficial sources regarding Romania's geological potential

<table>
<thead>
<tr>
<th>Uranium domestic resources *</th>
<th>[USD/kgU]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified</td>
<td>6700</td>
</tr>
<tr>
<td>Reasonable assured</td>
<td>3100</td>
</tr>
<tr>
<td>Inferred</td>
<td>3600</td>
</tr>
<tr>
<td>Undiscovered</td>
<td>6000</td>
</tr>
<tr>
<td>Prognosticated</td>
<td>3000</td>
</tr>
<tr>
<td>Speculative</td>
<td>3000</td>
</tr>
</tbody>
</table>

* "Uranium 2011: Resources, Production and Demand"

U needs | Time of operation
---------|-------------------
U1 1970 tU | 30y+10 y (2036)
U2 2059 tU | 30y (2037)
U3 1611 tU | 18y (2050)
U4 1343 tU | 15y (2050)
Total U needs | 6983 tU
**SR1: Consistency with resource availability**

**CR1.1 fissile/fertile material** \( F_j(t) > D_j(t), \) for \( t < 100 \) y

Quantity of Uranium available for use is larger than the Uranium needs for the considered time horizon (2050) ???

It depends on the available resources !!!

U resource base and production capacity (acc. to Red Book 2011, IAEA “Analysis of Uranium Supply to 2050”, OECD/NEA study “Trends towards sustainability in the nuclear fuel cycle”, and WNA study “The global nuclear fuel market”) is more than adequate to meet projected U requirements for the foreseeable future (up to 2050) even in case of substantial growth of nuclear power.

U prices do not influence significantly the cost of electricity production by nuclear power plants.
UR1: Consistency with resource availability

CR1.1 fissile/fertile material \( F_j(t) > D_j(t), \text{ for } t<100 \text{ y} \)

U needs per year are: \(~180 \text{ tU} (2014-2031, 2038-2050)\)
\(~270 \text{ tU} (2032-2034, 2037)\)
\(~360 \text{ tU} (2035-2036)\)

Upgrading of U ore processing & fuel fabrication facilities is mandatory
UR1: Consistency with resource availability

CR1.2 non-renewable materials $Q_j(t) > D_j(t)$, for $t<100 \text{ y}$

Quantity of non-renewable materials (zirconium, heavy water have been considered) available for use is larger than the quantity needed for the considered time horizon (2050)*.

Zr needs /year = ~ 5t Zr for each CANDU6 unit …. Total of ~400 t Zr

*According to national strategies in nuclear field and mining industry.

OECD/NEA study “A Preliminary Assessment of Raw Material Inputs that Would be Required for Rapid Growth in Nuclear Generating Capacity,” 2011, conclusion: for all raw materials global known resources are large and it is to be expected that production would increase in time to meet rising requirements for use in a rapidly increasing global NES.
UR1: Consistency with resource availability

CR1.3 power supply to NES \[ P(t) \geq P_{\text{NES}}(t) \text{ for } t < 100 \text{ y} \]

Power available for use is larger than the power required for NES operation taking into account the considered time horizon (2050)*.

* According to corporation reports for Cernavoda NPP (internal services consumption represents 8% from the net production; 98% goes for electricity and 2% is transformed in heat)
Sustainability of Nuclear Energy System in Romania

Resources Availability considering INPRO Methodology

**UR1: Consistency with resource availability**

**CR1.4 end use of uranium  \( U_{eu} > U_0 \)

Uranium end use energy delivered by the NES /Mg nat U is larger than \( U_0 \), maximum end use achievable for an existing NES (CANDU 6) with a once-through NFC.

- Using NEST, \( U_{eu} \) was calculated for Cernavoda NPP CANDU units, \( U_{eu} = 57.25 \) GWh/tU, being used 153 tU to produce 1 GWy.

- \( U_0 \) value was calculated also using NEST, the IAEA INPRO Methodology for Resources Annex IV and NEA study “The Economics for Nuclear Fuel Cycle”, \( U_0 = 55 \) GWh/tU
UR1: Consistency with resource availability

CR1.6 end use of other non-renewable resources $C_i > C_0$ ??

End use energy delivered by the NES /Mg non-renewable resource consumed is larger than $C_0$, maximum end use achievable for an existing NES (CANDU 6) with a once-through NFC ??

• share of $\text{UO}_2$ in the typical HWR fuel assembly (24 kg) is $\sim$ 92% of the total assembly weight, the rest of 8% being for Zr.

• Total consumption of Zr = 400 t, taking into account the time horizon (2050)
UR2: Adequate net energy output

CR2.1 amortization time \( T_{EQ} \ll T_L \)

Energy payback time of a CANDU6 NES, \( T_{EQ} \), is much shorter than the lifetime \( T_L \) of the system.

\( T_L = 30 \text{y} \) for a CANDU6 unit, except for U1 extension life to 40 y

\( T_{EQ} = \sim 18-20 \text{ months} \)
Conclusions

National priorities and expectations include:

- updating national strategy for Nuclear Field development, market oriented, focusing on the transition to the long-term regionally sustainable NES, with a high level of public acceptance to national strategy in Radioactive Waste Management

- a new national “pact for energy” concept, based on the national energy security of supply enhancement, within a well balanced power mix, to increase Romania’s contribution in EU energy market

- No nuclear energy in Romania’s energy mix is not acceptable based on the need to: satisfy the national energy demand; assure an equilibrate national energy mix; reduce GHG emissions; deliver a cheap energy to final consumers in the conditions of the society sustainable development, according to EU energy policy requirements
Conclusions

- Generally speaking, in the approach considered, the sustainability of the NES is assured, all the INPRO Methodology criteria being fulfilled.

- The difficulty in promoting the above conclusion resides in the lack of information/uncertainties/contradictory information regarding the real amount of domestic resources, both for fissile and raw materials.

- In this light, many international accepted studies and forecasts have been used.

- Currently we don’t have a consistent and comprehensive system to assess sustainability of national Nuclear Energy Systems; on-going planned NESA exercise as proper tool to address this issue.
Thank you for your attention!