“Implementation of the INPRO Economy Indicators to Assess Nuclear Competitiveness - Argentine Experience”.

Vienna
26-29 August 2014

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Strategic Planning Management
National Atomic Energy Commision
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ARGENTINE
WEM
STATUS
The Wholesale Electricity Market

9 Electric Regions

23 Provinces

May 2014
The Wholesale Electricity Market

Installed Capacity: 31427 MW

May 2014

HYDRO 11095.0 35.3%
ST 4441.2 14.1%
GT 4073.8 13.0%
CC 9205.3 29.3%
WIND 190.0 0.6%
PV 8.2 0.03%
NUCLEAR 1010.0 3.2%
DIESEL 1403.6 4.5%
Others Renewables

Others Renewables
The Wholesale Electricity Market

Gross Generation

Average Jan- May 2014

- Fossil: 68.3%
- Hydro: 27.2%
- Nuclear: 4.0%
- Renewables: 0.5%
- Others: 0.5%

Net Generation

- Fossil: 55.3%
- Hydro: 25.2%
- Nuclear: 3.7%
- Renewables: 0.5%
- Others: 0.5%

Net-to-Gross Efficiency

- Fossil: 82.9%
- Hydro: 96.7%
- Nuclear: 95.4%
- Renewables: 99.5%
- Others: 99.5%

Annual Load Factor

- Fossil: 52.7%
- Hydro: 45.7%
- Nuclear: 84.3%
- Renewables: 95.5%
- Others: 95.5%
Natural Gas Demand 2013

- Natural Gas not available for FPP

- Natural Gas available for FPP & other uses
### Fossil Fuels Prices & Consumption

<table>
<thead>
<tr>
<th>Fossil Fuel</th>
<th>Fuel Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Natural GAS</td>
<td>7.5 U$S/MMBTU</td>
</tr>
<tr>
<td>Natural GAS Imported from BOLIVIA</td>
<td>11.5 U$S/MMBTU</td>
</tr>
<tr>
<td>LNG Import</td>
<td>18.6 U$S/MMBTU</td>
</tr>
<tr>
<td>FUEL OIL</td>
<td>685.2 U$S/t</td>
</tr>
<tr>
<td>GAS OIL</td>
<td>830.1 U$S/m3</td>
</tr>
<tr>
<td>COAL</td>
<td>172.2 U$S/t</td>
</tr>
</tbody>
</table>

![Graph showing consumption of fossil fuels from Jan to Dec 2013]
STRATEGIC & ENERGY PLANNING
Since 2003 CNEA uses MESSAGE model (IAEA) and since 2006 the Secretariat of Energy uses MESSAGE to model the energy supply. In 2008 the National Energy Plan 2008-2025 was finished. The first review was held in 2011 and the second in 2013 (2014-2030).

The competitiveness of nuclear energy is permanently evaluated in CNEA, in order to advise the authorities of the Institution and the National Government.

Levelized Generation Costs and other Indicators of the INPRO methodology are permanently used in the evaluation of the competitiveness of nuclear energy.
### Strategic & Energy Planning

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>Plant Life (y)</th>
<th>Overnight Cost (U$S/kWe)</th>
<th>LUEC (U$S/MWh) r = 8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear PHWR</td>
<td>40</td>
<td>4500</td>
<td>99.5</td>
</tr>
<tr>
<td>CC (mix NG+GO)</td>
<td>25</td>
<td>1100</td>
<td>108.9</td>
</tr>
<tr>
<td>CC (GO)</td>
<td>25</td>
<td>1100</td>
<td>171.5</td>
</tr>
<tr>
<td>ST (FO)</td>
<td>25</td>
<td>950</td>
<td>187.3</td>
</tr>
<tr>
<td>ST (Coal)</td>
<td>25</td>
<td>2100</td>
<td>101.3</td>
</tr>
<tr>
<td>Hydro</td>
<td>60</td>
<td>2900</td>
<td>123.2</td>
</tr>
<tr>
<td>Wind</td>
<td>20</td>
<td>2600</td>
<td>101.9</td>
</tr>
</tbody>
</table>

The current mix of Natural Gas burned during the year is a proportion of 70% local NG, 15% NG imported from Bolivia and 15% imported LNG. Besides, during the winter period is always necessary to use substitutes fuels, to replace the NG not available.
ARGENTINE NUCLEAR SECTOR
Argentine Nuclear Sector

- **CNEA**
  - Research, development, training and services

- **CONUAR**
  - Nuclear Fuel Production

- **ENSI**
  - Heavy Water Production

- **NASA**
  - Nuclear Power Plants Operator

- **FAESA**
  - Zircaloy tubes and special alloys Production

- **FUESMEN**
  - Nuclear medicine school

- **INVAP**
  - Engineering and services

- **DIOXITEK**
  - UO2 Production

Timeline:
- 1950
- 1976
- 1981
- 1986
- 1989
- 1991
- 1994
- 1997
NPP in Operation

ATUCHA I

- Capacity: 362 MWe
- Siemens Technology
- Plant factor: 74.75%
- Operating since 1974
- Total Generation: 2.6 Million MWh

EMBALSE

- Capacity: 648 MWe
- CANDU Technology - AECL
- Plant factor: 85.1%
- Operating since 1984
- Total Generation: 3.5 Million MWh
NPP in Operation

- Capacity: 745 MWe
- Siemens Technology
- Start up operation: June 3, 2014
- Current supply: 50% of its capacity

NPP in Construction

- Capacity: 25 MWe
- Complete national design
- PWR type
- Self pressurized
- Cooled with natural convection light water;
- Safety systems based on advanced concepts
REACTIVATION OF NUCLEAR ACTIVITY
Since 2006 the Government has set a clear strategic position in Nuclear Activities, through numerous actions that constitutes new milestones in developing the National Strategic Plan for Nuclear Activity.

LAW 26566 / Dec 2009. National Congress approved the National Nuclear Law, giving a specific framework for the nuclear sector and declaring of interest the nuclear current and future projects.

Accompanying these policies, CNEA has developed the STRATEGIC PLAN 2010 - 2019 according to the Government guidelines for the Nuclear Activity.
Reactivation of Nuclear Activity in Argentina

Atucha II

Embalse - Life Extension Plan

Future 4º NPP

CAREM 25 NPP

U Enrichment

U Mining

D₂O Production
INPRO
APPLICATION
Economic Area
Argentine Experience
INPRO WEM Considerations

- Considering that the 3 operating NPPs in Argentina are PHWR type, the interest in using INPRO Methodology assessed in a PWR reactor of 3rd generation (1000 MWe), is to introduce a new kind of nuclear technology in the country. Because of that, the Government is nowadays taking into account the PWR technology as a possibility for future NPPs.

- For the comparison were used several FPPs\textsubscript{A}: Combined Cycle burning only Natural Gas imported from Bolivia, other option of Combined Cycle using a national mix of Natural Gas and Gas Oil as a substitute fuel during the winter period (70\% - 30\% Annual relation), and Steam Turbine burning Coal.

- Finally, the most competitive FPPs\textsubscript{A} is the Combined Cycle burning only Natural Gas imported from Bolivia (FPP\textsubscript{A1}).
## INPRO Economic Area – Argentine Data

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Nuclear</th>
<th>FPP&lt;sub&gt;a&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUES</td>
<td>U$S/MWh</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>NEP MWe</td>
<td>MWe</td>
<td>1000</td>
<td>800</td>
</tr>
<tr>
<td>tLIFE</td>
<td>years</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>Lf</td>
<td>%</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>Decommissioning cost</td>
<td>U$S/MWh</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>ON</td>
<td>U$S/kWe</td>
<td>5000</td>
<td>1100</td>
</tr>
<tr>
<td>Contingency cost</td>
<td>% ON</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Construction time</td>
<td>years</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>O&amp;M FIX</td>
<td>U$S/kWe</td>
<td>170</td>
<td>8.6</td>
</tr>
<tr>
<td>O&amp;M VAR</td>
<td>U$S/MWh</td>
<td>1</td>
<td>4.6</td>
</tr>
<tr>
<td>Fuel price</td>
<td>U$S/kgU ; U$S/MMBTU</td>
<td>2700</td>
<td>11.5</td>
</tr>
<tr>
<td>Nuclear Backend cost</td>
<td>$/KgSF</td>
<td>1100</td>
<td>-</td>
</tr>
<tr>
<td>Spent NF burnup</td>
<td>MWd/kg</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>Net thermal efficiency</td>
<td>%</td>
<td>33</td>
<td>54</td>
</tr>
</tbody>
</table>
### INPRO Application - Argentine Case

<table>
<thead>
<tr>
<th>r (%)</th>
<th>Technologies</th>
<th>IN1.1: LUEC</th>
<th>AL1.1: k*Cₐ ( k = 1 )</th>
<th>AL1.1: ( C_N &lt; k*C_A )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>U$S/MWh</td>
<td>U$S/MWh</td>
<td>Y/N</td>
</tr>
<tr>
<td>8</td>
<td>PWR</td>
<td>91.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FPPₐ₁: CC 100% NG BOL</td>
<td>93.1</td>
<td>93.1</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>FPPₐ₂: CC NG75% GO 25%</td>
<td>104.8</td>
<td>104.8</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>FPPₐ₃: CC NG70% GO 30%</td>
<td>109.4</td>
<td>109.4</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>FPPₐ₄: ST COAL</td>
<td>107.0</td>
<td>107.0</td>
<td>Y</td>
</tr>
<tr>
<td>10</td>
<td>PWR</td>
<td>107.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FPPₐ₁: CC 100% NG BOL</td>
<td>95.7</td>
<td>95.7</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>FPPₐ₂: CC NG 75% GO 25%</td>
<td>107.4</td>
<td>107.4</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>FPPₐ₄: ST COAL</td>
<td>111.9</td>
<td>111.9</td>
<td>Y</td>
</tr>
</tbody>
</table>
**INPRO Application - Argentine Case**

- **FPPs_A** is the Combined Cycle burning only Natural Gas imported from Bolivia (FPP_A1).

### UR2: Ability to finance

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>CR2.1: Attractiveness of investment</th>
<th>CR2.2: Investment limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IN2.1: Financial figures of merit.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AL2.1: Evaluation of figures of merit.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LA2.1.1: IRR_N &gt; IRR_L</td>
<td>AL2.2.1: IN2.2: Total investment</td>
</tr>
<tr>
<td></td>
<td>LA2.1.2: ROI_N &gt; ROI_L</td>
<td>AL2.2.2: LA2.2: Affordability</td>
</tr>
<tr>
<td></td>
<td>LA2.1.3: NPV_N &gt; NPV_A</td>
<td></td>
</tr>
</tbody>
</table>

**LA2.1.1:**

\[ \text{IRR}_N \geq \text{IRR}_L \]
\[ \text{IRR}_L = \text{r} + \alpha \]
\[ \alpha = 2\% \]

**LA2.1.2:**

\[ \text{ROI}_N > \text{ROI}_L \]
\[ \text{ROI}_L = \text{IR} + \text{RP} \]
\[ \text{IR} = 0.55\% \]
\[ \text{RP} = 6\% \]

**LA2.1.3:**

\[ \text{NPV}_N > \text{NPV}_A \]

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>IN2.1.1</th>
<th>IN2.1.2</th>
<th>IN2.1.3</th>
<th>LA2.1.1</th>
<th>LA2.1.2</th>
<th>LA2.1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>10.1</td>
<td>11.9</td>
<td>1122.1</td>
<td>10</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>FPP_A1</td>
<td>19.8</td>
<td>20.3</td>
<td>696.6</td>
<td>7</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>LA2.2.1</th>
<th>LA2.2.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>INV = ON + IDC</td>
<td>INV &lt; INV_L</td>
</tr>
<tr>
<td>FPP_A1</td>
<td>6300.0</td>
<td>Y</td>
</tr>
</tbody>
</table>

- **Y/N**
- **MU$**

* INV_L : Confidential information that is in the process of bidding*
CR3.1 - Maturity of design - IN 3.1 Technical and regulatory status: PWR is the most proven and massive nuclear technology globally. The 3rd generation reactor evaluated in this case will have previous precursors from which to learn in other countries.

AL 3.1: Licensing of design sufficiently mature: Nuclear Regulatory Authority in the country has enough experience to license, control and solve on time all new challenges related with this technology, especially after construction of the PWR reactor (CAREM 25), with a license of construction recently approved for next four years, adding experience on its issues.

CR3.2 Construction schedule - IN 3.2 Project construction & commissioning times used in economic evaluation: 5 years

AL 3.2: Times of construct. & comissioning sufficiently accurate: National experience in building of the 3 NPPs, (Atucha II recently completed) as of local and exported RR, in addition to engineering work for the construction of CAREM 25. Sufficient trained human resources and expertise to carry out the construction of a PWR within the time scheduled, with important participation of local labor.
INPRO Application - Argentine Case

UR3 - Investment risk (cont.)

CR3.3 - Uncertainty of economic input parameters.
IN 3.3 Sensitivity analysis (cost & financing) has been performed:
Using the NEST platform is possible to analyze the risks associated with variability in the most important economic input parameters (r, ON, construction time), and to evaluate if nuclear option is still valid in a range of reasonable variability. Moreover, the government considers “strategic” the nuclear development in the country, accepting k values greater than 1.

AL 3.3: Sensitivity to changes in selected parameters acceptable to investor:
The case in question using NEST has a higher RI than 1. The sensitivity analysis was done changing the variables above mentioned, keeping in mind the RI higher than 1.
INPRO Application - Argentine Case

UR3 - Investment risk (cont.)

CR3.4 - Political environment - IN 3.4 Long term commitment to Nuclear option:
Since 2006 National Government has decided diversifying the energy matrix, growing hydro, other renewals and nuclear participations. In 2009, National Congress approved the National Nuclear Law, giving a specific framework for nuclear sector, declaring of interest current and future nuclear projects.

AL 3.4: Commitment sufficient to enable a return of invest: Participation of several suppliers with high percentage of financing and moderate interest rates in the international bidding for next Argentine NPP (two modules PHWR and PWR), so bidders consider acceptable the risk to invest in the country.

UR4 (Flexibility)

CR4.1-Flexibility. IN 4.1 Are the innovative NES components adaptable to different markets?

3rd generation reactor evaluated in this case will have previous precursors in other countries, developed in different markets, showing its flexibility capacity. AL 3.1: Yes
COMMENTS & FINAL CONSIDERATIONS
INPRO Comments & Final Considerations

- CNEA was established in 1950 and therefore has over 64 years of experience in the nuclear field. Energy planning is a continuous activity in CNEA, using IAEA tools and models.
- National Government supports nuclear energy. (Positive Political Climate).
- National Congress approved the National Nuclear Law, giving a specific framework for the nuclear sector and declaring of interest the current and future nuclear projects.
- Electricity generation with NPP’s is competitive in Argentina compared to FPP’s alternatives considered in the WEM.
- INPRO Methodology provides relevant indicators for economic and financial evaluation.
- The ultimate goal of the INPRO Methodology application is to confirm that the assessed NES fulfills all the criteria and hence the user requirements and basic principles. Therefore represents a long-term sustainable system for Argentina.
INPRO Comments & Final Considerations

- INPRO Methodology provides relevant indicators for economic and financial evaluation.

- The results of the sensitivity analysis were performed on the values of key economic parameters such as the overnight cost, discount rate, construction time, and the NPP capacity factor.

- The government's strategic decision to strengthen the Argentine nuclear sector is based on the policy for socioeconomic development, and considers the ranges over which these variables can be modified so that nuclear project remains competitive and attractive compared to alternative energy projects (FPP) in the country.

- Moreover, the possible variation of parameters such as the discount rate or the overnight costs affect all the alternative technologies, which together with the expected increase in the price of fossil fuels, strengthen the energy strategy.
THANK YOU FOR YOUR ATTENTION