Belarusian NPP.

Terms of economic efficiency and the INPRO methodology

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Outline of presentation

- Results of energy system planning
- Economic assessment of the project by the INPRO methodology
- The current status of the Belarusian nuclear power project
- Problems of NPP introduction to the Belarusian energy system
- Cost-effectiveness of the Belarusian NPP and the INPRO methodology
Results of energy system planning
Results of energy system planning
Results of energy system planning (cont.)

- Nuclear power (NP) is needed for long term sustainability of energy supply in Belarus.
- Decision to build 2 nuclear blocks of 1200 MW each was taken.
- Share of nuclear capacities – about 12% in 2018, 25% in 2020, 17% in 2035.
- Share of nuclear electricity – 18% in 2018, 35% in 2020, 25% in 2035.
Nuclear energy system of Belarus

Mining and milling of uranium ore

Conversion

Enrichment

Fuel manufacturing

Purchase nuclear fuel

Intermediate storage of Spent Fuel (50 years in dry storage in transportable containers)

Reprocessing of Spent Fuel

High level waste final disposal

High level waste final disposal

2 NPP units 1170 MW each, future extension has to be defined.

Belarus

Minsk
# NESA results

## Economics

### Main initial data:

<table>
<thead>
<tr>
<th>Names</th>
<th>Units</th>
<th>NPP</th>
<th>Coal PP</th>
<th>Nat gas PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net electric power</td>
<td>kWe</td>
<td>2*1170</td>
<td>4*660</td>
<td>6*400</td>
</tr>
<tr>
<td>Average Load factor</td>
<td></td>
<td>0.92</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>Overnight cost</td>
<td>$/kW</td>
<td>3715</td>
<td>1175</td>
<td>755</td>
</tr>
<tr>
<td>Price per unit of electricity sold</td>
<td>mills/kWh</td>
<td>125</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Natural U purchase cost</td>
<td>$/kg U</td>
<td>130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel price</td>
<td>$/GJ</td>
<td></td>
<td>6.14</td>
<td>8.97</td>
</tr>
<tr>
<td>Nuclear fuel enrichment cost</td>
<td>$/kg U</td>
<td>163</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear fuel fabrication cost</td>
<td>$/kg U</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear fuel backend cost</td>
<td>$/kg U</td>
<td>500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Economics (cont.)

Results of economic indicators calculations

<table>
<thead>
<tr>
<th>Name</th>
<th>PP</th>
<th>Unit</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levelized Unit Energy Cost</td>
<td>NPP</td>
<td>cent/kWh</td>
<td>8.02</td>
</tr>
<tr>
<td></td>
<td>Coal PP</td>
<td></td>
<td>8.57</td>
</tr>
<tr>
<td></td>
<td>Gas PP</td>
<td></td>
<td>8.33</td>
</tr>
<tr>
<td>Internal Rate of Return</td>
<td>NPP</td>
<td></td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td>Coal PP</td>
<td></td>
<td>0.314</td>
</tr>
<tr>
<td></td>
<td>Gas PP</td>
<td></td>
<td>0.540</td>
</tr>
<tr>
<td>Investment volume/limit</td>
<td>NPP</td>
<td>mln. $</td>
<td>11835/6221</td>
</tr>
<tr>
<td></td>
<td>Coal PP</td>
<td></td>
<td>3361/4147</td>
</tr>
<tr>
<td></td>
<td>Gas PP</td>
<td></td>
<td>2027/3110</td>
</tr>
</tbody>
</table>
Conclusion to Section Economics

- Advantage of nuclear energy technology LUEC in front of the best technology using fossil fuel gives background to confirm satisfaction of INPRO methodology criteria, connected with the cost of nuclear electricity.

- All INPRO methodology criteria and requirements on robustness of nuclear technology planned for introducing are satisfied. Project of nuclear power plant construction in Belarus has a sufficiently big sensitivity to such parameters as the load factor of NPP, overnight cost of NPP, fuel cycle backend cost and delay of construction.
The value of investment needed for construction of planned nuclear power plant in Belarus almost twice greater than investment limit accepted by possibilities of electricity market of Belarus.

Verifying of license status of planned nuclear power plant shows that absence of operated nuclear energy source of design planned for construction in Belarus forwards to conclusion about not satisfaction of criteria on “design maturity”.
Present status of NPP Project

- The PSAR expertise carried out and a license for the construction of the first unit has been obtained.

- The first unit is under construction.

- Application has been filed and PSAR of the Belarusian NPP second block is under the expertise.
Present status of NPP Project
Present status of NPP Project
Present status of NPP Project
## Energy system status by 1.01.2014

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity, MW</td>
<td>9221,2</td>
</tr>
<tr>
<td>Installed capacity of Belenergo, MW</td>
<td>8506,2</td>
</tr>
<tr>
<td>Installed capacity of small PP, MW</td>
<td>715,0</td>
</tr>
<tr>
<td>Electricity production by Belenergo PP, bln. kWh</td>
<td>28,515</td>
</tr>
<tr>
<td>Electricity production by small PP, bln. kWh</td>
<td>2,809</td>
</tr>
<tr>
<td>Electricity import, bln. kWh</td>
<td>6,370</td>
</tr>
<tr>
<td>Electricity consumption, bln. kWh</td>
<td>37,694</td>
</tr>
<tr>
<td>Load factor of Belenergo PP</td>
<td>0,383</td>
</tr>
<tr>
<td>Peak power, MW</td>
<td>~ 6000</td>
</tr>
<tr>
<td>Necessary power with reserve, MW</td>
<td>~ 7000</td>
</tr>
</tbody>
</table>
Daily Load Curve (31.03.2014)
LUEC as a function of Load Factor

\[ y = 9.99x^2 - 25.27x + 22.81 \]

Graph showing the relationship between LUEC and Average Load Factor (Lf). The equation \( y = 9.99x^2 - 25.27x + 22.81 \) is displayed on the graph, indicating the quadratic relationship between the two variables.
LUEC as a function of Overnight Cost

\[ y = 0.00152x + 2.37278 \]
Natural Uranium Cost & LUEC

\[ y = 0.002851x + 7.648188 \]

LUEC, cent/kWh

Natural Uranium Cost, $/kg

y = 0,002851x + 7,648188
Nuclear Fuel Fabrication Cost & LUEC

\[ y = 1 \times 10^{-10}x^3 - 2 \times 10^{-7}x^2 + 0.0004x + 7.9375 \]

\[ R^2 = 0.9999 \]
Nuclear Fuel Backend Cost & LUEC

\[ y = 2 \times 10^{-8}x^2 + 0.0002x + 8.0391 \]

\[ R^2 = 1 \]
LUEC as a function of NF Backend Cost

\[ y = 2 \times 10^{-8} x^2 + 0.0002x + 7.9291 \]

\[ R^2 = 1 \]
IRR as a function of Average LF

\[
y = -0.0439x^2 + 0.2245x - 0.0096
\]

\[
R^2 = 0.9999
\]
IRR as a function of Overnight Cost

\[ y = 6 \times 10^{-9}x^2 - 8 \times 10^{-5}x + 0.3652 \]

\[ R^2 = 0.9999 \]
Conclusion

- Such a key indicator of economic efficiency of Belarusian nuclear power plant, as LUEC, has a high degree of sensitivity to such parameters as Overnight Cost and Average Load Factor. This indicates the importance of the implementation of NPP project indicators during its construction and operation.
- LUEC of Belarusian nuclear power plant is less sensitive to changes in nuclear fuel cycle parameters of the project.
- Financial performance of the Belarusian nuclear power project are also less sensitive to changes in the parameters of the NPP and nuclear fuel cycle.
- INPRO methodology implemented in the NEST support package, provides a simple tool for economic analysis of nuclear energy systems and a clear representation of the results.
- The foregoing is the personal view of the author.
Thank you for your attention!