The Sustainability Assessment of the Nuclear Energy Systems with SMR RITM-200M by INPRO Methodology

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Afrikantov OKBM JSC is a company of ROSATOM State Corporation, of Atomenergomash JSC, the Machine Building Division

**ESTABLISHMENT DATE**
December 27, 1945

**MISSION**
to serve the national interests, to develop and deliver to the market high-quality high-technology solutions and products

**VISION 2030**
one of the largest engineering companies of the ROSATOM’s machine building division, a designer, a manufacturer and a complete supplier of nuclear plants and high-technology products for related economy sectors

Afrikantov OKBM JSC has a powerful potential as it combines its research capacities and designers’ capabilities, which shortens the path from an idea to its implementation.
THE PURPOSE OF THE WORK is to assess, using the INPRO methodology, the sustainability of a nuclear generation project in the area of economics in order to verify the long time sustainability of the nuclear energy system—the Optimized Nuclear Floating Power Unit (hereinafter, OFPU) equipped with the RITM-200M reactor plants (hereinafter, the INPRO Assessment).

TASKS

- To analyze the INPRO methodology in the area of economy and to analyze the NEST* used for a technical and economic analysis

- To do a comparative analysis of nuclear generation projects and LNG** fueled projects having various technical and economic characteristics

- To do an integrated analysis and make an assessment of the calculated results

- In terms of economy, to validate the sustainability of the OFPU with the reactor plants RITM-200M using the methodology

* NEST is a special Nuclear Economics Support Tool that enables calculations of basic investment parameters (calculating the levelized unit energy cost (LUEC), internal rate of return (IRR), return on investment (ROI), net present value (NPV), and to do a sensitivity analysis);
**LNG is Liquefied Natural Gas
Sustainable Development Goals

Ensure access to affordable, reliable, sustainable energy sources

Nuclear energy may contribute significantly to achieving the Sustainable Development Goals

The sustainability analysis of energy projects is required, including in terms of technical and economic parameters

IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)

NES sustainability assessment by the INPRO Methodology implying the compliance with the IAEA requirements

The 2030 Agenda for Sustainable Development
The assessment of a project by the INPRO methodology is a self assessment, which implies that IAEA requirements be met. Such assessment may be an important step in the development of small-sized designs, will identify problematic issues and solutions that require further studying.

Currently, there are certain difficulties in starting to implement new projects. The difficulties are associated with public acceptability, safety assessment, competitiveness and legal regulation for the construction and operation of small-sized nuclear power plants. The assessment by the INPRO methodology is an opportunity to demonstrate the efficiency and economic feasibility of SMR project implementation.

It is possible to publish the accomplished assessment in the form of a TECDOC report.
The object of study

**Optimized Floating Power Unit (OFPU)** is a non-self-propelled berth-connected ship fitted with a double bottom and double sides all along the hull, a well-developed superstructure stretching all along the ship, a reactor compartment amidships and a crew accommodation block in the fore part.

- **2 reactor plants**
  - **RITM-200M**
- **Service life**
  - **up to 60 years**
- **Refueling interval**
  - **up to 10 years**
- **Electric power**
  - **100 MW**
- **Reactor plant thermal power**
  - **up to 198 MW**

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**Ship hull optimization**

<table>
<thead>
<tr>
<th>FPU Akademik Lomonosov</th>
<th>Optimized Floating Power Unit (OFPU)</th>
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</thead>
<tbody>
<tr>
<td>LENGTH</td>
<td>144.2 m</td>
</tr>
<tr>
<td>BEAM</td>
<td>30 m</td>
</tr>
<tr>
<td>DRAFT</td>
<td>5.6 m</td>
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<tr>
<td>DISPLACEMENT</td>
<td>21,000 t</td>
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</table>

*according to the preliminary design results*
The Object for Comparison

For the purposes of this work, a floating power unit was selected that is fueled with liquefied natural gas (hereinafter, LNG) and that is based on data calculated by Afrikantov OKBM JSC. The final product cost was calculated as defined by operation of the energy sources on a conditional site in the south-eastern regions of Russia.

The LNG-fueled floating electricity-generating station is a berth-connected two-deck ship with a double bottom and double sides and with the superstructure on the ship’s stern.

- The design provides for floating fuel storages having the fuel capacity for 30 days.
- Fuel is transported to the station by bunkering tankers.

- Construction time: 4 years
- Service life: 40 years
- Capacity factor: over 0.7
- Endurance: 30 days
- Output to consumers: electricity
- 50 MW

LNG IS BELIEVED TO BE MORE ENVIRONMENTALLY FRIENDLY THAN OTHER FOSSIL FUELS

*ACCORDING TO WWF DATA
Requirements and Criteria for Assessing Sustainability in the Area of Economics

“Nuclear energy and associated products must be available and affordable for all potential users.”

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Indicator</th>
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</thead>
<tbody>
<tr>
<td>Energy cost</td>
<td>$CN \leq k*CA$</td>
</tr>
<tr>
<td>Investment parameters</td>
<td>$IRR_N \geq IRR_A$ $ROI_N \geq ROI_A$ $NPV_N \geq NPV_A$</td>
</tr>
<tr>
<td>Risks</td>
<td>Risk acceptability</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Meets the requirements of a number of markets</td>
</tr>
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</table>

The Nuclear Economics Support Tool (NEST) is used

NESA Economics Support Tool
International Project on Innovative Nuclear Reactors and Fuel Cycles
Division of Nuclear Power
Department of Nuclear Energy
International Atomic Energy Agency

$LUEC = \sum_{t=t_{start}}^{t_{end}} C(t) (1+y)^t + \sum_{t=t_{start}}^{t_{end}} O(t) (1+y)^t + \sum_{t=t_{start}}^{t_{end}} F(t) (1+y)^t$
Results. Electricity Cost (1/3)

**REQUIREMENT:** The cost of electricity supplied by nuclear energy sources, taking all costs into account, should be competitive with that of alternative energy sources that are available for a said case in the same time frame and geographic region.

To correctly compare economic characteristics of projects based on LNG and OFPU, combinations of energy sources based on LNG and OFPU have been calculated that match each other in terms of output power and operation life.

**Inputs and assumptions**
- Discount rate, 7%;
- Construction period for the LNG FPU, 4 years; for OFPU, 6 years;
- Output power supplied to shore from one OFPU, 100 MW; from one LNG FPU, 50 MW;
- OFPU refueling interval, 10 years; LNG OFPU, 30 days;
- Inflation is not included, and tax deductions are not accounted for;
- The payback period was calculated from the start of the power plant construction.

THE ASSUMPTIONS MAY GENERATE AN ERROR OF UP TO 25%, BUT THE DYNAMICS AND KEY TENDENCIES IN THE CALCULATED RESULTS ARE CORRECT.
Results. Electricity Cost (2/3)

CAPEX FOR SERIALLY MANUFACTURED POWER UNITS MAY BE REDUCED TO 40%

IF THE LNG PRICE GROWS TO $12 FOR MMBtu, THE FUEL COMPONENT IN THE EXPENDITURES WILL GROW BY 30%
The energy cost (LUEC*) in the LNG project is **20% higher** than the energy cost in the OFPU project.

The largest contribution to the energy cost for the gas energy generation is made by the **fuel component**, 82.27%;

The largest contribution to the cost of the OFPU output energy is made by **capital cost**.

### Investment Parameters

The efficiency characteristics include the internal rate of return (IRR), return on investment (ROI), net present value (NPV).

<table>
<thead>
<tr>
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<th>IRR, %/100</th>
<th>ROI, %/100</th>
<th>NPV, %</th>
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<tbody>
<tr>
<td>OFPU</td>
<td>11</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>LNG FPU</td>
<td>9</td>
<td>13</td>
<td>70</td>
</tr>
</tbody>
</table>

**ELECTRICITY RATE: 11 CENT/kW*h**

The energy cost and investment attractiveness criteria are met.

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*LUEC is a Levelized Unit Energy Cost with account of the levelized unit life cycle amortization cost (LUAC), levelized unit life cycle operation and maintenance cost (LUOM) and levelized unit life cycle fuel cost (LUFC)*
Results. **Project Maturity and Flexibility**

**REQUIREMENT:** The risk of investment in a nuclear energy system should be acceptable to investors.

- Risks erroneously accounted for may affect the future project implementation, which—without any doubt—will affect the major investment characteristics and result in an output product price changing for the worse
- The risk factors are passable. An in-depth analysis is required to study the measures to compensate for the risks

**REQUIREMENT:** The Nuclear Energy System should have a sufficiently flexible innovative approach to be able to evolve and adapt in a manner that provides a competitive product for as wide a range of plausible markets as possible

- **Modularity**
  - An “n+1” concept of cyclic replacements, that is, creating an energy fleet that consists of a number of OFPUs, one of which is a substitution unit
- **Non-electrical applications**
  - A possibility of using additional equipment to meet potential consumers’ needs (like, desalination)
- **Execution**
  - A possibility of developing a line of OFPUs based on RITM-series reactors to meet the customer’s needs

THE CRITERIA FOR PROJECT RISKS AND FLEXIBILITY MAY BE CONSIDERED SATISFIED
1. **VISUALIZATION OF CALCULATIONS**
   The sensitivity analysis calculations are insufficiently visualized because formulas are inside the program, and the user does not see how exactly a certain value (box) impacts the final result.

2. **INPUT DATA**
   The practice shows that designers have calculational templates (financial and economic models), which enables project competitiveness assessment to be done in a short time. The NESA requires inputs that are unusual for our practice; hence, inputs take a long time to be prepared.

3. **FLEXIBILITY**
   The NEST may be a supplementary tool rather than a replacement for financial and economic models in MS Excel.

4. **ANALYSIS METHODOLOGY**
   The functions should be broadened to make calculations for energy systems. It may be a system with the power substituted for the repair/refueling time and/or a system following a principle of the FPU-based Energy Fleet.
Conclusions

- At the moment, at the existing inputs from the preliminary design, the OFPU project is a sustainable nuclear energy system in terms of the INPRO methodology in the area of economics.

- As part of obtaining results in the area of sustainable development of nuclear energy systems, the NEST is a convenient and illustrative software tool.

- The comparative analysis of gas-fueled and nuclear electricity generation sources identified that the OFPU type floating energy source with nuclear generation is competitive vs. gas-fueled electricity generating sources in the same power range (from 100 MW).

- The gas-fueled solutions are sensitive to fuel (gas) prices—gas price fluctuations result in higher LUEC/LCOE, and consequently reduce the project profitability. The nuclear-generation-based business is more controllable and predictable.

- In terms of the final cost of energy, the high CAPEX is the most complicated aspect in the OFPU project. In this case, the conditions for the Customer may be optimized through different contracting types. For example, it may be the Energy Fleet business model that uses the experience with implementing the Akkuyu Nuclear Power Plant project in Turkey under a Build-Own-Operate Contract.

- The OFPU project investment attractiveness complies with the INPRO criterion, that is, the investment parameters for the nuclear generation are better (equal in terms of ROI) than for the LNG FPU project.

- The analysis has shown that the OFPU project, as any technological project, has risks that may have a negative impact upon the project implementation. Nevertheless, developing an action plan to compensate for the risks at each OFPU project stage will make it possible to develop a strategy for implementing the project under different conditions and to reduce possible consequences of the risks.
Thank you for your attention

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