**COMMENTS**

To presentation slides at the Technical Meeting IAEA “Advances in Non-Electric Applications of Nuclear Energy and on Efficiency Improvement at Nuclear Power Plants”:

**“The Dual-use of Nuclear Power Plants through the use of heat pumps with carbon dioxide”**

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| **№** | **Name** | **Comments** |
| 1 | The Dual-use of Nuclear Power Plants through the use of heat pumps with carbon dioxide | Dear Ladies and Gentlemen,  This report presents a promising technology for dual-use nuclear power plants, which can increase energy, economic and environmental efficiency of nuclear energy |
| 2 | HPS-NPP Technology | The proposed technology is based on the transformation of waste heat of the nuclear power plant to parameters of heating supply systems through the use of high-power heat pumps on carbon dioxide and its delivery to the consumer at a distance up to 100 km |
| 3 | Heat Pumps Technology | Heat pumps of different capacity are widely used in the world and the number reaches about 90 million machines.  Basically it is the machines of power of several kilowatts, which are used in autonomous heating systems.  Number of high-power heat pumps of capacity up to 30 MW is relatively small.  Maximum heating capacity of heat pump station is 360 MW, which provides half of the heating load Stockholm, Sweden. |
| 4 | Heat Pumps Parameters | Most of heat pumps use freon as the working fluid.  However, solving large-scale district heating is only possible with the use of heat pumps for carbon dioxide.  This is explained as follows:  - Implementation of the gas-liquid thermodynamic cycle allows to heat water to high temperature with the minimum pressure ratio in the compressor and the maximum energy efficiency;  - Thermophisical properties of carbon dioxide (high pressure and high density) allow to design compact heat exchangers and compressors for high-power heat pumps. |
| 5 | Source of waste heat of NPP on PWR-1200 | As an example, on the slide is shown principal scheme of nuclear power plants with PWR-1200.  Thermal power of reactor - 3,200 MW.  Electric power of generator - 1,200 MW.  At the same time, 2,000 MW of waste heat is given to the environment due to the evaporation of water in the volume of 5000 m3. |
| 6 | NPP on PWR-1200 of one-use | On the slide is shown traditional scheme of use of nuclear energy.  This scheme provides production of electric energy in the amount of 8.3 million KWh per year, while the annual deadweight loss of water are more than 40 million m3, which is a significant factor limiting the development of nuclear energy.  In addition, this factor contributes to negative changes in the environment in the area of accommodation nuclear power plant, as a result of the exposure of heat and humidity. |
| 7 | NPP on PWR-1200 of dual-use due to HP with electrically drive | On the slide is shown scheme of dual-use nuclear power plants through the use of heat pumps with electrically driven.  This scheme makes it possible to diversify energy products of NPP and significantly improve the economics of nuclear power.  Environmental performance of nuclear power plants can also be improved by reducing the flow of water up to 10 times.  In addition, the use of electric creates the conditions for the creation of carbon-free energy in the region of the NPP. |
| 8 | NPP on PWR-1200 of dual-use of due to HP with natural-gas drive | On the slide is shown scheme of dual-use nuclear power plants through the use of heat pumps with natural-gas drive.  This scheme allows to halve the consumption of natural gas compared to gas boiler and also allows a significant improvement in economic performance of nuclear energy. |
| 9 | Prospective consumers of heat of HPS-NPP | Housing facilities;  Production and processing of agricultural products;  Biotechnology, including production of biofuels, biological products and dietary supplements;  Desalination plants;  Recycling of municipal waste and household waste;  Production of construction materials. |
| 10 | Principal scheme of HPS-NPP for example SPB & LAES-2 | On the slide is shown principal scheme of the heat supply system of St. Petersburg due to the use of waste heat of Leningrad NPP-2. |
| 11 | Heat transporting system from Leningradskaya NPP-2 to Saint-Petersburg (80 km) | On the slide is shown a principal scheme of the heat transport from the Leningrad NPP-2 to St. Petersburg.  The length of the heating duct - 80 km in diameter - 1400 mm, insulation thickness of 140 mm.  Transmitted power is 2,500 MW, while the heat loss during transport is less than 2%.  A similar project is being developed in Finland for the heat transport from the Loviisa NPP-2 to the Big Helsinki (85 km). |
| 12 | Prospective Heating Supply System of Saint-Petersburg (2025) without HPS-NPP  Prospective Heating Supply System of Saint-Petersburg (2025) with HPS-NPP | On the slide is shown traditional heating supply systems of St. Petersburg until 2025, which provides for the input of additional thermal power in the amount of 10 000 MW, which will require additional combustion 5 billion m3 of natural gas per year.  Below is a perspective scheme of using waste heat of NPP due to the use of heat pumps.  As can be seen from the scheme, the use of waste heat of nuclear power plant for heating supply systems of St. Petersburg can save up to 5 billion m3 of natural gas per year. |
| 13 | HP CO2 100 MW | On the slide is shown a heat pump on carbon dioxide with capacity of 100 MW, designed EKIP to order of Rosenergoatom.  The main indicators of this heat pump were presented and discussed at the European Heat Pump Summit 2013, Nurnberg, Germany.  Technical and economic performances of this heat pump outperform the best world analogues. |
| 14 | Centrifugal compressor of HP CO2 100 MW | On the slide is shown a centrifugal compressor of heat pump on carbon dioxide with capacity 100 MW.  This machine can be equipped with an electric or gas drive.  Design of compressor allows to create heat pumps on carbon dioxide with capacity up to 200 MW. |
| 15 | Heat exchangers of HP CO2 100 MW | On the slide is shown heat exchangers of the heat pump on carbon dioxide with capacity 100 MW.  Technical and economic performance of these heat exchangers are superior to the best world analogues. |
| 16 | Conclusion | 1. Technical and technological solution of HPS-NPP is based on the Russian engineering. 2. HPS-NPP Technology can be implemented at both the nuclear, organic and hydro power plants, which opens up new opportunities to optimize the energy balance in the regions of their placement. 3. The implementation of HPS-NPP Technology is a new line of non-electric use of nuclear power in the path of construction of carbon-free energy.   Thus, the energy, economic and environmental performance of the proposed technology HPS-NPP can significantly increase the share of nuclear energy in the global energy balance and reduce the payback period of existing and new nuclear power plants. |
| 17 | Information about author | Thanks for your attention! |