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# INVOLVEMENT OF INRNE-BAS IN THE BULGARIAN NUCLEAR ENERGY PROGRAMS AND THE EXPERIENCE GAINED IN OPERATING OF THE RESEARCH REACTOR IRT-SOFIA

## INTRODUCTION

With a combined population of more than 57 million people, an area of 550,000 $km^2$, and a favourable geographical location (the Black Sea to the east, the Adriatic Sea to the west and the Mediterranean Sea to the south), the Southeast European region plays an important role as a "bridge" to Africa, Middle East and Asia. Given the constantly increasing need for energy throughout the SEE Region, the concerns about global warming due to rising $CO_2$ emissions, and the notion that renewable energy (e. g., hydro, wind, solar, biomass and nuclear) will be among the primary energy sources of the future, energy companies are allocating resources to energy projects in Southeast Europe. Two major projects for gas deliveries from Asia to Europe are underway – the European Nabucco pipeline, which goes through Bulgaria and Romania, and the Russian South Stream pipeline projected to cross Bulgaria and Serbia. Bearing in mind the development of common policy in EU for substitution of fossil fuels with Renewable Energy Sources (RES) and the national targets for sustainable development, based on clean energy, energy security and liberalization of energy markets, Bulgaria is expected to be a dynamic energy market over the next 5 years.

## BULGARIA AND NUCLEAR ENERGY

Since 1956, the Bulgarian government has favoured the use of nuclear power for electricity. In 1957 Bulgaria ratified the Statute of the International Atomic En-

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ergy Agency (IAEA) and became one of the IAEA states-founders. In June 1957 the Committee for Peaceful Use of Atomic Energy (CPUAE) within the Council of Ministers was established as the specialized state body to co-ordinate the activities connected with the use of atomic energy in the country and in the international community. The controlling and co-ordinating activities of CPUAE were directed towards the scientific research activities, medicine, industry and agriculture. The 2 MW IRT–2000 research reactor was built at the outskirts of Sofia in that time and put in operation in 1961. In 1966 an agreement was signed with the Soviet Union for supply of commercial pressurized water reactors, decisive for the country's energy program. In the absence of Bulgarian regulatory body of nuclear and radiation safety at that stage, these functions defaulted initially to Soviet standards. The former Act on the Use of Atomic Energy for Peaceful Purposes from 1995 was substituted in 2002 by the Act of the Safe Use of Nuclear Energy, last amended and supplemented in 2010. The Bulgarian Nuclear Regulatory Agency (BNRA) after its transformation from CPUAE in 1995 has enforced new Rules of Procedure of the State regulation of the safe use of nuclear energy and ionising radiation, the safety of radioactive waste management and the safety of spent fuel management. At present, INRNE takes part in formulating the additional measures to be undertaken on national level in response to the Fukushima accident.

Bulgaria joined the producers of commercial nuclear energy in 1974 and 149 power reactor years of operational experience were accumulated since then by using the six units of the Kozloduy nuclear power plant on the Danube River border with Romania. Four 440-megawatt reactors of the Kozloduy NPP were shutdown as a condition for Bulgaria's joining the European Union in 2007. The second WWR -440 pair incorporated many of the much-improved safety features of the V–213 model. The third still operational pair is the larger WWR–1000 units, model V–320. The closure and subsequent decommissioning commitments concerning Kozloduy 1–4 are included in Article 30 of the Act of Accession 2005. After shutdown in rapid sequence of the first pair of WWR–440 units model V–230 in 2002 followed by units 3 and 4 in 2006, 35 percent of the electricity production in 2010 was generated by the units 5 and 6, each of 1000 MW (e). An upgrade and modernisation program for the V–320 units 5 and 6 extended to 2006, but there is no great concern about their safety, which conform well to international standards. The units are currently licensed to 2017 and 2019, and there are plans to extend their operating lifetimes beyond the current 30 years to 50 years. In January-March 2011 these two units have registered production of 4,506,941 MWh of electricity, which is a record for quarterly production of electricity since they were launched in 1988–1993. Compared with the first quarter of 2010, units 5 and 6 have produced 297,000 MWh more electricity, which will bring BGN 20 M more revenues for the NPP.

Bulgaria has announced its determination to proceed with the construction of its second nuclear facility, the Belene NPP. Site works started in 1980 with a view to building four or six large units and construction of the first WWR–1000 V–320 unit started in 1987. This was partly built (40%, with 80% delivery of equipment) but was

aborted in 1991 due to lack of funds. The Belene NPP construction was officially restarted in September 2008 – though only preliminary site activities were carried out – and was a year later suspended by the new Government due to doubts for unclear investment efficiency and for energy diversification issues. In November 2010 Bulgaria invited Serbia, Croatia and Macedonia to take equity of 1%, 1.5% or 2% in the Belene project. Croatia declined, but Serbia said that it is interested in a larger stake of 5%. A European strategic investor for the project is believed necessary.

## BULGARIAN RENEWABLE GREEN ENERGY SECTOR

The EU quota on renewables for Bulgaria specifies that renewable energy should account for 11% of gross energy consumption after 2010 and 16% after 2020. Bulgaria has taken major legislative steps to meet the quota, leading to a boom in entrepreneurial interest. In 2010 the output from renewable energy sources was increased by 67 percent to 5,509 gigawatt-hours as new hydropower plants, wind and solar parks went into operation. In fact, renewable green sources accounted for 15 percent of total energy output, exceeding the 11 percent target set by the European Union.

Large hydropower plants with total installed capacity of 1,919 MW accounted for the bulk of output. Newer small hydropower generators, with capacity of less than 5 MW each, had combined capacity of 241 megawatts in 2010, a 13 percent increase from 2009. Total wind capacity rose 38 percent to 465 MW, while solar parks' total capacity was 21.4 MW. This way almost 87 percent of the green energy was produced by hydroelectric power plants and 12.5 percent by wind power plants. The new law that entered into force in late April 2011 will further encourage developers to build green power plants by ensuring legislatively that local companies are buying their electricity at preferential prices for a period of 12 years for wind energy, 15 years for hydro energy, and 20 years for solar and biomass energy. Here is to note that Bulgaria is with solar potential similar to that of Northern Spain and exceeding Germany by 10–15%. The feed – in tariff is higher, while real estate and labour expenses are lower compared to those in other European member states, making investing in solar plants in this country attractive. Considering that approximately 90 percent of the country's land is arable, agricultural land, or forests, the potential for the development of biomass projects looks promising with about 3,400 MW (e) of technical potential identified.

## ELECTRICITY EXPORTS

Bulgaria has been a traditional exporter of energy to neighboring countries with ambitions to export energy in the future. Electricity consumption in Bulgaria has been growing only slowly since 1980 but with the closure of the nuclear units at the end of 2006, electricity exports have dropped slightly. Nevertheless, the electricity exports were doubled from 3700 GWh in 2009 to 7500 GWh in 2010. The updated National Energy Strategy from November 2010 provides some additional 2 GW of nuclear power to be constructed. There are two independent options in

the document: to implement the Belene NPP project and to build two new nuclear units at the existing Kozloduy NPP.

## BULGARIAN NUCLEAR POWER PROFILE

By May 2011 Bulgaria makes use of three licensed nuclear sites: the NPP Kozloduy encloses four shutdown reactors and two operational, a Spent nuclear fuel storage (SNFS) commissioned in 1990 for fuel from WWR -440 and WWR -1000 reactors and a Dry spent fuel storage facility (DSFSF, first stage commissioned in May 2011, storage for at least 50 years) for fuel assemblies (FA) from reactors WWR–440 (Container system with using of CONSTOR 440/84 type of containers with natural convection air-cooling and capacity of 84 FAs), the NPP Belene site, and the research reactor IRT-Sofia. An additional licensed site is used for the state-owned repository of radioactive waste generated from research, medicine, agriculture and industry. The main challenges in front of the Bulgarian nuclear energy sector could be specified as follows: preparation for long term operation of Kozloduy NPP units 5 and 6; approval of the design and authorization of the construction of Belene NPP; improvement of the regulatory practices through the implementation of the regulatory guides' development and updating program.

## INRNE ACTIVITIES IN THE NUCLEAR FIELD

The INRNE is carrying out up-to-date support of the milestone problems in Bulgaria in accordance with the tendencies and technologies in the nuclear energy sector. The supporting tasks range from contributions to the European Union programs for development of new fusion and fission technologies to safety and risk assessment of existing Russian WWER units. INRNE houses as well the headquarters of the EURATOM Bulgaria. Fusion blanket materials are studied for the ITER project. Actions are planned for long term operation, in accordance with the internationally recognized operational experience participation in the large scale modernization program implemented at the Kozloduy 5–6; Level 1 and Level 2 probability risk assessments (PRA reports) are being updated for the Kozloduy NPP units. The Level 2 and level 3 PRA studies are providing assessments of the risk for the population and environment in consequence of postulated severe nuclear accidents. The reactor core nuclide inventory and the spent fuel characteristics of WWER reactors as well as problems with safe transport and storage of spent fuel are also investigated. The studies of WWER fuel performance, modelling and experimental support are of utmost importance. The outcome helps improving of the understanding between fuel suppliers, designers, researchers and users, thus contributing to the enhancement of NPP operational safety and reliability. Thermomechanical analysis of the in-reactor fuel rods performance and evaluation of the fuel rod failure are performed with the TRANSURANUS computer code at applying boundary conditions obtained by the RELAP5/MOD3.3 code.

INRNE is involved in the SARNET (Severe Accident Research NETwork of Excellence) project of EURATOM. The staff took part in corium-concrete interaction

experiments carried out by CEA, Cadarache and contributed to the Benchmark recalculations. Long-term experience is accumulated in analyses of loss-of-coolant accidents (LOCA) and Station Blackout (SBO). The calculations are executed with the latest version of ASTEC v2 code. Computer simulations and analysis of data from experiments using the PANDA thermal-hydraulics test facility for investigation of the behaviour of reactor containment and related phenomena were carried out. The water chemistry and radiochemistry problems of WWER reactors are also of interest. The research is focused on the optimization of water chemistry technologies and management to ensure reliable fuel performance at high burn-up and in ageing plants and is in the frame of IAEA-coordinated research programmes.

The contribution of INRNE staff has proven record of high quality contributions to the field of neutron interactions with nuclei and practical applications in the development of innovative nuclear technologies. Neutron-induced reaction cross section data are needed in different field of science and technology. Accurate neutron data are of great interest as well for testing nuclear models. The nuclear waste problem is another example and INRNE staff is participating in the European research program for transmutation of high-level nuclear waste in accelerator driven system – IP EUROTRANS.

From early 1970-ies until 2006 the INRNE was operating the near-surface Repository "Novi Han" for radioactive waste from nuclear methods and applications in medicine, research and industry. The Repository underwent several modernizations of its diagnostic and monitoring systems as well as some reconstructions aimed to increase its capacity, radiation safety and physical protection. It was equipped with a hot cell and a facility for treatment of high level radioactive waste as well as deactivation area for heavy transport and goods. The Repository is including separate disposal units closed but not sealed that are subject of monitoring and control, reinforced storage casks for irradiator units, reinforced storage containers for sealed radioactive sources in transport containers or original working devices, as well as full size railway transport containers. Part of the INRNE staff is engaged with the duties of the emergency team for elimination of radiation accidents outside the Kozloduy NPP. Besides offering expert and consultant benefits to public trend performing, applied scientific research has been carried out for assurance of safety management of radioactive wastes and development of new methods for radioactive waste storage.

## RESEARCH REACTOR IRT-SOFIA

INRNE is the licensed operator of the research reactor IRT–2000 (RR). The reactor was designed and constructed from 1958 to 1961. It is a pool type reactor, cooled and moderated with light water. First criticality was reached in September 1961. It was operated safely with a mixed (LEU-HEU) core for 28 years until July 1989 at power levels agreed upon user demands up to 2000 kW. The principal areas of reactor usage ranged from basic and applied research, to technological and com-

mercial applications. Moreover, it was an important place for university and postgraduate education and training.

With the years passed, Sofia grew in size and presently IRT–2000 is undergoing refurbishment and conversion into a civil reactor with low power up to 200 kW designed to operate with low enriched uranium fuel IRT–4M. A General Plan for partial dismantling was developed for identifying the roles, chain of command and responsibilities within the dismantling team, interfaces with supporting organizations involved at the INRNE site. It was successfully implemented in 2009. The disassembly of reactor systems, removal of the reactor core and storage of old equipment was carried out in strict compliance with Bulgarian radiation safety regulations. The upgraded IRT–200 will have two vertical channels in the fuel assemblies to supply fast neutron flux $3.10^{12}$ n/cm$^2$s; two vertical channels in beryllium blocks to supply thermal neutron flux 8. $10^{12}$ n/cm$^2$s; seven horizontal channels outside the aluminium vessel of the reactor core with fast neutron flux 1,6. $10^{12}$ n/cm$^2$s; and thermal neutron flux 5. $10^{11}$ n/cm$^2$s on the core vessel; six vertical channels outside the aluminium vessel of the reactor core with fast neutron flux 2. $10^{12}$ n/cm$^2$s; and thermal neutron flux 7. $10^{12}$ n/cm$^2$s on the core vessel; channel for boron captured neutron therapy (BNCT) with epithermal neutron flux 0,9. $10^9$ n/cm$^2$s. Education, training and raising the qualification in the nuclear field continue to be in the focus as well as good practices to address safety culture and emergency preparedness with a view to the Fukushima lessons and the Belene NPP new design in an open transparent manner.

All highly (HEU) and low-enriched (LEU) Russian-origin nuclear fuel was repatriated to Russia beginning in 2003 (HEU fresh fuel: IRT–2M, 36% enrichment) and completing in 2008 (spent fuel HEU: C–36, 36% enrichment; LEU: EK–10, 10% enrichment)) in the frames of the Russian Research Reactor Fuel Return Program (RRRFR). The work, equipment, approvals, organizational procedures, and international agreements to complete these shipments were developed by INRNE under the surveillance of IAEA and DOE National Nuclear Security Administration (NNSA). RRRFR is one of multiple nuclear nonproliferation programs administered by the NNSA Global Threat Reduction Initiative (GTRI) and works in close cooperation with the IAEA and the RF Rosatom State Corporation.

## BULGARIAN NUCLEAR SOCIETY

The INRNE programs are closely related with the activity of the Bulgarian Nuclear Society (BgNS). BgNS, founded in1991, is a voluntary society of 16 corporate bodies and more than 400 individuals, joint in virtue of their professional interests in the field of science, technologies and practice on the peaceful uses of nuclear energy. An important task is to disseminate nuclear knowledge and help the public better understand the benefits of nuclear technology. For more information – http://www.bgns.bg/Information.htm.