BRILLIANT

Grant Agreement: 662167

WP1. Deliverable D1.10

Roadmap of Baltic region cooperation in nuclear research and technology fields

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Date of issue of this report: **20 June, 2018**

Project funded by the European Commission under the Horizon 2020 Euratom Framework Programme for Nuclear Research &Training Activities (2014-2018)		
Dissemination Level		
PU	Public	X
RE	Restricted to a group specified by the partners of the BRILLIANT project	
CO	Confidential, only for partners of the BRILLIANT project	

Start date of project: 01/07/2015 Duration: 36 Months

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PART 1. INTRODUCTION

The main objective of this report is to develop a Baltic Roadmap identifying areas of prospective cooperation on nuclear research and technology. The results of SWOT analysis as well as proposals from BRILLIANT WP2, WP3 and WP4 are used during development of roadmap. The implementation of the roadmap will strengthen institutional cooperation in the region and will help not only to cooperate more efficiently in nuclear R&D areas, but also will address topics related to maintaining competences in nuclear safety and other related fields important in all stages of life for nuclear installations – design, construction, commissioning, operation, decommissioning, spent fuel and radioactive waste management. Therefore, the roadmap includes topics for regional cooperation in areas such as - Research, Development, Education, Training and Competence Building.

Based on the competences and strengths of BRILLIANT partners, the concept of virtual EuroBALTIC Research Institute with Regional Baltic Nuclear Centers is developed and presented in the D1.8, where the following specialized centers to be established in each country of BRILLIANT partners are proposed:

- Baltic Reactor Research Centre (Poland),
- Baltic Center for Nuclear Fuel Cycle Studies (Sweden),
- Baltic Center for Nuclear Safety and Energy Security (Lithuania),
- Baltic Center for Advanced Nuclear Coolant Technology Development (Latvia),
- Baltic Center for Nuclear E-education (Estonia).

The roadmap presents the areas of common interest of the Baltic Centers in nuclear research and development (Part 2) as well as in education, training and

competence building (Part 3), considering competences, strengths and opportunities of each Baltic Center. The Roadmap promotes cooperation of the Baltic countries and integration of the Baltic region to the common European Research Area in the nuclear energy research field.

This document is treated as a living text and is open for further comments, modifications and upgrade to take into account rapidly changing situation in participating countries: Lithuania, Latvia, Poland, Estonia, and Sweden.

PART 2. COOPERATION IN NUCLEAR RESEARCH AND DEVELOPMENT

2.1 Materials research

The number of research organisations in Baltic region have experiences in materials research field. There are examples of fragmented participation of research institutions from Baltic region in separate European projects (LEI in FP7 project MATTER, H2020 project INCEFA PLUS, University of Latvia in H2020 project EUROFUSION, etc.). The establishment of Baltic Reactor Research Centre in Swierk (NCBJ, Poland) can significantly increase potential of Baltic region in European and other international projects in materials research field. The following areas of common interest for Baltic research organisations in the materials research field are identified:

- Development of new materials for current and future generations of nuclear reactors;
- Irradiation and testing of irradiated materials;
- Material analysis using neutron beams;
- Corrosion and material studies in liquid metals and magnetic fields.

The leading organization in the materials research field in BRILLIANT project is NCBJ operating the only research reactor in the Baltic Region. The MARIA reactor, nearby hot cell laboratory and radiopharmaceutical production centre in NCBJ would be key research infrastructure for materials research. The experimental facilities for material available in the LEI, UL and other Baltic research organisations would serve as additional research infrastructure.

2.2 Nuclear safety

The "Strategic Energy Technology (SET) Plan" of EU identifies nuclear fission as one of the key low carbon energy technologies. **Nuclear safety** is primary priority in all stages of life of nuclear installations – design, construction, commissioning, operation, decommissioning, spent fuel and radioactive waste management. This topic is important at both national and international level. In Lithuania decommissioning of Ignalina NPP is ongoing and safety is important issue in performing equipment dismantling and decontamination, as well as in radioactive waste management (including safety of spent nuclear fuel and radioactive waste management and storage facilities). In Poland it is important to be prepared for safety assessment of new NPPs, which are planned to be constructed, and for possible development of High Temperature Gas cooled reactor technology. As nuclear facilities in the case of nuclear accident do not recognise borders, safety of nuclear installations is issue of high importance also at international level. Thus, for Baltic countries it is important also to understand and properly evaluate safety of Belarussian NPP, which is under construction at the site located close to the Baltic countries (40 km from Vilnius).

The leading organization in the nuclear safety research field in BRILLIANT project is LEI, continuously participating in the international projects in this field (ongoing H2020 projects IVMR, INCEFA PLUS, FASTNET, etc.). In safety assessment LEI researchers apply different computer codes for analysis of different phenomena and covering different aspects important to safety (thermal-hydraulic, neutron kinetics processes, probabilistic safety analysis, structural-integrity analysis, assessment of radiological consequences).

Other research institutions also have experiences in some aspects related with safety analysis. University of Latvia (UL) has liquid metal loops and test stands operating with different liquid metals: Na, Li, Pb, PbBi, Hg (possibility to extend to other metals). UL researchers perform modelling and calculations of electromagnetic pumping of liquid metals and other magnetohydrodynamic systems. This infrastructure and experience of

UL researchers is important in performing research and developments in the safety of generation IV fast neutron nuclear reactors. FTMC and UT apply software codes for the modeling of radionuclide migration from radioactive waste repositories, human and biota exposure dose assessment, those are important components of safety assessment.

Considering existing competence and infrastructure in Baltic research institutions, the following areas of common interest for Baltic research organisations in the nuclear safety research field are identified:

- Safety evaluation of plants under construction considering international and national requirements and guides as well as Fukushima accident lessons,
- Nuclear plant safety in the case of external hazards (seismic, flooding, aircraft crash, etc.),
- Severe accident scenarios and phenomena,
- Safety of new generation (Generation IV) nuclear plants,
- Safety of nuclear plant under decommissioning.

2.3 Analysis of the role of nuclear energy in long-term sustainable energy supply

In the frames of BRILLIANT project was created a basis for application of regional approach in assessing of the role of the nuclear energy in long-term sustainable energy supply taking into account different aspects:

- Technical and economic attractiveness,
- Impact of nuclear energy on security of energy supply,
- Macroeconomic impact of nuclear programs.

The different computational tools were used for each of three above aspects, the data were collected for development of regional models', the trainings were performed for application of these models. This creates a good basis for further assessment of the role of the nuclear energy on the regional level, and results of such modelling will be useful for decision makers. This is especially important for small countries, where introduction of large energy infrastructures (NPPs) meets various barriers.

The activities on regional level in this field fit very well with the *Energy Union Strategy in the EU* (EC initiative announced in February 2015), because the energy security and regional cooperation are key components in this strategy. In May 2014 the European Commission set out in its *Energy Security Strategy*. The security of energy supply is predominant factor for all countries in the Baltic region. Cooperation among countries around the Baltic Sea create basis for assessment of national and regional security of energy supply, including nuclear energy implementation impact on security level. Assessment of security of energy supply addresses such important aspects of Energy Union as diversification of energy sources, reducing of EU countries dependency on energy imports and fighting against climate change.

2.4 Nuclear Fuel Cycle Studies

As it is foreseen in the deliverable D1.8, the Baltic Center for Nuclear Fuel Cycle Studies will be coordinated by the municipality of Oskarshamn and Nova Research and Development Center (Nova FoU). Other Baltic research organisations will contribute to the activities related with Nuclear Fuel Cycle Studies by performing analytical and experimental research, e.g. FTMC, UT, and KTH have experience in the Nuclear Fuel Cycle studies area. FTMC uses simulation codes (MCNP and SCALE) and can perform the Nuclear Fuel Cycle and Materials characterization with NFCSS, whereas KTH and UT have

jointly been developing the FANCSEE software and have experience with VEGAS and other codes with similar objectives.

The municipality of Oskarshamn and Nova FoU have worldwide unique nuclear facilities related to the Nuclear Fuel Cycle:

- 3 BWR reactors,
- Interim Storage of all Swedish spent fuel – CLAB,
- Hard Rock Laboratory (500 m under the ground), which is a model of the geological disposal site,
- The Canister Laboratory.

Oskarshamn community and SKB are already deeply involved in a broad international cooperation focused on geological storage of the spent nuclear fuel. Many international groups have access to research projects and many of partners have their own research agenda.

Oskarshamn may become a European Facility/Center for Nuclear Fuel Cycle Studies and a demonstration facility for the Geological Storage of the Spent Nuclear Fuel.

PART 3. COOPERATION IN EDUCATION, TRAINING AND COMPETENCE BUILDING

The Baltic countries share the worldwide concern about the availability of high competence trained staff in nuclear energy field. The closure of Ignalina NPP in Lithuania decreased interest in nuclear energy among the young generation, and the number of experienced staff is decreasing due to high level of retirement. In Poland, an important problem is related to a clear generational gap between experienced staff and the young researchers. Latvia and Estonia also wish to increase their competences in the nuclear energy field. Therefore, education, training and competence building is issue of high importance for Baltic region. This issue could be difficult for each individual country, but the use of existing research and training infrastructures on regional level could be effective. Moreover, the limited resources of aging experienced personnel should be used in the most efficient way, it is thus logical to organize training and educational activities on regional, not only national levels. We overviewed the applicability of existing research infrastructures in Baltic countries for education, training and competence building purposes and identified following possibilities for their regional use:

- The course of radiation protection and trainings for accelerators and reactor operators by use Experimental 30MW Reactor MARIA in the NCBJ (Poland);
- The use of experimental facilities in KTH (Sweden) for following fields of specialized training:
    - Advanced nuclear fuel laboratory for training in Advanced nuclear fuel research and manufacturing (nitride fuel, carbide fuel),
    - Heavy metal coolant laboratory with TALL 3D experimental loop for mastering of heavy metal technology for Gen IV reactor, thermal hydraulics of heavy metal coolant,

- High pressure water-steam loop for training and competence building in the thermal hydraulics of BWRs and PWRs and High Performance LWR (Gen IV);

- The use of Oskarshamn (Sweden) nuclear infrastructure for following fields of training:
  - Training on the management of spent nuclear fuel by use of CLAB (central interim storage of the spent nuclear fuel) and Äspö Hard Rock Laboratory (a model of the geological storage of spent nuclear fuel),
  - Training on the geology of final repositories by use of Geological logging lab and Äspö Hard Rock Laboratory,
  - Training on the technologies for spent nuclear fuel encapsulation in the Encapsulation Laboratory (laboratory for encapsulation of spent nuclear fuel),
  - Training of reactor operators using the Full scale simulator of the O3 reactor in the Oskarshamn Nuclear power plant,
  - Use of Oskashamn nuclear infrastructure with all above listed installations and its worldwide recognized and respected human potential for training in public communication on nuclear energy in Baltic countries (incl. new build NPPs, geological repository for disposal of nuclear fuel, etc.). Oskarshamn experts have vast experiences in conducting a social dialogue on location of the Spent Nuclear Fuel facility. This aspect is very important to other Baltic countries, where construction of such facilities often meets negative reaction from municipalities and public.
- Training in the LEI on application of computer codes for safety analysis and licensing of nuclear facilities. Available computer codes for:
  - thermal-hydraulic processes,

  - probabilistic safety analysis,
  - neutron kinetics,
  - structural-integrity analysis,
  - assessment of radiological consequences;
- Training at FTMC, KTH, and UT on application of computer codes for:
  - Nuclear Fuel Cycle, and Materials characterization,
  - modeling of radionuclide migration from radioactive waste repositories, human and biota exposure dose assessment
- Use of experimental nuclear physics laboratory and neutron physics laboratory in FTMC for training on neutron activation and ion beam methods for the non-destructive characterization of materials (with fast neutrons and slow neutrons), measurements for the determination of material composition important for radiological characterization of radioactive waste, as well as other fields: radiation biology, environmental studies, measurements in health physics;
- Use of experimental nuclear physics laboratory and mass spectrometric laboratory in FTMC for training on Radiochemistry and nuclear spectroscopy: application of specific radiochemical methods for the preparation of samples for radiological characterization of nuclear objects for decommissioning purposes;
- Use of liquid metal loops and test stands with different liquid metals for trainings in fields of magnetohydrodynamics, liquid metal technology, flow analysis and measuring, numerical simulation, heat transfer, experiment data acquisition.

PART 4. CONCLUSIONS

The roadmap presents the areas of common interest of the Baltic Centers in nuclear research and development (Part 2), as well as in education, training and competence building (Part 3).

The areas of cooperation in nuclear R&D were identified considering the basis for cooperation formed within the Brilliant project and also the results of SWOT analysis (Deliverable D1.8), where on the basis of competences and strengths of BRILLIANT partners the concept of Regional Baltic Nuclear Centers was developed. Four main areas of cooperation were identified:

- Materials research,
- Nuclear safety,
- Analysis of the role of nuclear energy in long-term sustainable energy supply,
- Nuclear Fuel Cycle Studies.

A number of subareas are also identified for these main areas.

The regional use of existing research infrastructures is needed for education, training and capacity building in order to deal with the needs of qualified personnel in nuclear energy field. The applicability of existing research infrastructures in Baltic countries for education, training and competence building purposes is overviewed and fields of training are proposed for their regional use.

The prepared Baltic Roadmap identifying areas of prospective cooperation on nuclear research and technology in the Baltic region is a live document. Regular workshops of participating Baltic organisations will be organised to update developing research topics considering ideas for new regional, European and international research

projects depending on the available calls and possible changes of priorities in the nuclear energy field. The periodical revisions of the Baltic Roadmap will be implemented identifying the changes in the areas of Baltic Sea region cooperation in nuclear energy field.

The realisation of Baltic Roadmap will promote regional cooperation in the identified fields of research, education, training and competence building and will escalate international exchange of PhD students and young researchers.