Addressing Societal Challenges Through Advancing the Medical, Industrial and Research Applications of Nuclear and Radiation Technology

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Among non-power uses of nuclear reactors and accelerators, is neutron scattering as a key tool for advanced research in the field of material science for multidisciplinary applications. Like synchrotrons, reactors and accelerator-based facilities have been built in Europe and the world to provide highly competitive services tailored to cover the research needs of a very wide and diverse user community.

According to the results of a study commissioned by ESFRI and recently published (http://www.esfri.eu/sites/default/files/u4/NGL_CombinedReport_230816_Complete%20document_0209-1.pdf), the European landscape of neutron sources consists of 17 facilities, out of which 15 are nuclear reactors and 2 are spallation sources. 13 of these facilities run a user programme and serve a community of over 5500 users, offering of the order of 190 instruments jointly generating about 30.000 instrument-days per year to carry out over 4500 experiments per year. The capital replacement value of all sources was estimated to be about 6 B€ with integrated operational cost of the order of 300 M€ per year, with an overall economic impact presently evaluated as of the order of 11 B€.

Europe is at the forefront having led the field for the past 40 years due to its broad network of neutron sources, ranging from world-leading ones (ILL & ISIS) to the level of University reactors (Delft). The European Spallation Source, ESS, is under construction and scheduled to be fully operational by 2028. ESS will be the most powerful source in the world.

However, the majority of neutron sources are more than 50 years old and the major neutron facilities in Europe - ILL & ISIS - are fully mature. By the end of 2019, two reactor sources will be shut down. By 2025 Europe will, at best, have only 5 functioning neutron sources. This also will set the major challenge of how to handle the decommissioning phase of the facilities with the related problems of waste disposal. The anticipated neutron shortage will affect not only neutron-based research. Closing or building a neutron source will have an impact also on, among others, (radio) isotope provision, irradiation facilities (e.g. for silicon sensors), activation analysis.

There are close similarities with the aging of the infrastructures for isotope production and the unplanned out-stage of ageing reactors. So, some key questions come to mind:

1) What the eco-system of existing EU neutron sources could do to support radioisotopes and radiopharmaceutical production for medicine? What is the best framework to improve cooperation in this field?
   Although the core mission of the facilities would remain delivering neutron beams for research, synergies will help and isotope production could be framed as either an integrated activity of the facility (good examples are the Maria Reactor in Poland and the OPAL Reactor in Australia) or supported by specifically funded research projects. It seems to me that there is a need to increase **cross cooperation** and there is space for that without going into

commercial production of isotopes. Neutron sources, because of the traditional strong links with academia, are **centres of competence** and can provide training in isotope production, waste handling and disposal and analytical techniques like imaging.
Actually, small-and medium-sized neutron sources, which will be phased out soon, have a strong position in non-scattering activities related to isotopes and activation analysis, and offer instrumentation and methods that have a wide variety of application among industrial users. Thus, supporting new or renewed schemes of accelerator-based neutron production aimed at replacing capacity loss is needed.

2) How to mitigate the problem of unplanned shutting-down of aged facilities?
By **strategic planning** at European (or even global) level as also the decision to build a new major RIs, not only to shut-down a source, would invest the whole RI system and its community and needs coordination and a clear understanding of the whole lifecycle of the facility, from design to decommissioning.

By developing **novel technology** and **innovative models** like in the two examples.

- The ESS model for in-kind provision of accelerator, target and infrastructure components during construction phase, and possibly during operation and decommissioning, is an excellent example of getting industries from EU involved since the beginning as providers of top-level technologies under co-designing schemes requiring collaboration between the facility, scientists, engineers and the technical capacity of the industry. Also, innovative models to get industry involved as user of the ESS are under consideration.
- Accelerator-based sources
  To ensure a full return from new investment also a temporary capacity drop in the ecosystem that may endanger the basic resources (human capital of competences and skills) should be avoided. So novel concepts and technologies, like accelerator-based neutron source concepts for cost effective medium intensity sources beyond 2030, should be pursued, together with novel exploitation of existing facilities.