# TITLE: Metrology for New Generation Nuclear Power Plants

## Abstract

Currently global warming is one of the biggest challenges facing mankind. Ideally we would use renewables; hydroelectric, wind, geothermal, tidal, wave, solar, but these are unlikely to meet the energy needs of the EU. Europe does not have an abundance of renewable resources. This topic is motivated by the need to develop efficient and competitive nuclear energy technologies. The nuclear sector produces around one third of the electricity currently generated in the EU. It improves the Union's independence, security and diversity of energy supply and plays a key role in reducing greenhouse gases emissions. This research topic covers a number of key metrological problems that nuclear power has to address in the future to produce electricity. This topic does not include health physics, dosimetry or nuclear waste disposal, which fall under the scope of the health and environment calls.

Joint Research Projects (JRPs) submitted for this topic should aim to improve measurements in context related to; temperature, thermal properties, interaction cross sections and half-live of nucleides, absolute activation, thermo-chemical data and modelling and radiochemical analysis, all related to nuclear power plant applications.

## Conformity with the Work programme

This Call for JRPs conforms to the EMRP 2008 [1], section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

## Keywords

Nuclear, reactor, generation, fission, ionising, radiation, radioactive, activation, thermal, materials.

## Background to the Metrological Challenges

The EU is the world's largest producer of nuclear electricity (944.2 TWh(e) in 2005). Around a third of the electricity and 15% of the energy consumed in the EU comes from nuclear power plants. At the end of 2008, the EU-27 had 142 reactors in 15 Member States and the average age of these plants was around 25 years, with a lifespan of 40 years in general. On 25 June 2009 the EU established a common binding framework on nuclear safety and the Council Directive establishing a Community framework for the nuclear safety of nuclear installations was adopted [2]. Bulgaria, France, Slovakia and Finland have decided to build new nuclear reactors; Firm plans are underway in Romania and the United Kingdom and other EU countries, including the Czech Republic, Italy and the Netherlands. Lithuania together with Estonia, Latvia and Poland are also considering new nuclear power plants [3]. France for example currently produces about 80% of their electricity by nuclear means. In

the next 10 to 15 years $CO_2$ emissions from the production of electricity could be cut very substantially across Europe by expansion of nuclear fission. No other technology has that potential. Nuclear fission is a tried and tested technology, but developments and improvements are in progress. It should be noted, however, that some countries, such as Belgium and Germany have enforced laws on nuclear phase-out.

The current state of the art is Generation III nuclear reactors. In the EU these are EDF/Areva European Pressurised water reactors and in the USA they are Westinghouse AP1000 Pressurised water reactors. These reactor types are based on 20 to 30 year old designs. Design has not been able to advance rapidly as few reactors have been built in recent years. Much of the current nuclear generating capacity in Europe is coming to the end of its life.

New Generation IV reactors aimed at more socially acceptable nuclear power require development of primary and secondary standardisation methods, and improved nuclear data for radionuclides related to the new reactor types (Tritium, actinides, etc.). New reactor designs also require characterisation of the new materials proposed in these designs. Current thermo-chemical data for materials need to be significantly extended in the nuclear domain, particularly transuranic elements.

The most robust temperature measurement method currently uses thermocouples made of a nickel alloy. However when these are bombarded with high flux neutrons, transmutation takes place making the sensors unreliable and progressively degrading the thermocouple temperature measurement performance. Therefore new methods for the measurement of long-term in-reactor temperature need to be developed. The development of new generation IV fission reactor concepts, operating at high temperatures (up to 1000 °C and beyond), requiring the development and characterisation of advanced materials (refractory, ceramic, ceramic composite, graphitic, or coated materials).

## Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives below. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol.

The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

- Improved temperature measurement for nuclear power plant applications.
- Improved thermo-chemical data and modelling need to be used in nuclear design e.g. to simulate temperature related phase changes in unusual fuel conditions.
- Measurement of nuclear parameters such as interaction cross sections and half-lives after establishment of priority list of nuclides.
- Develop suitable reference metrological setups and methods for the measurement of thermal properties (notably thermal diffusivity, thermal conductivity, radiative properties, specific heat and thermal expansion) of advanced materials (refractory metals, ceramic, coated materials…) at high temperature (> 1000°C) and very high temperature (up to 2500 °C).
- Characterise reference materials for high temperature thermal properties measurements.
- Investigate the thermal properties of coolants (molten salt, liquid metals…), which could be used in generation IV reactors.

- Improved on-site radiochemical analysis.
- Development of techniques based on Digital Coincidence Counting (DCC) and Triple to Double Coincidence Ratio for radionuclide standardisation in order to yield absolute activity measurements in a more robust and efficient manner.
- Better analysis of detectors by Monte Carlo simulation and better spectral unfolding techniques.

## Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the "end user" community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the impact that your proposed JRP will have on any relevant Directives of the European Commission:

You should detail the impacts of your proposed JRP as detailed in the document "Guidance for writing a JRP.

In response to the need for standardised measurement techniques you should detail how your JRP results are going to:

- Feed into the development of standards and regulatory guidelines through the appropriate bodies
- Transfer knowledge to the nuclear industry

## Additional Information

References were provided by PRT submitters; proposers should therefore establish the relevance of any references.


[1] European Metrology Research Programme. Outline 2008 Edition - November 2008, http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5

[2] Council Directive 2009/…/EURATOM of XXX establishing a Community framework for the nuclear safety of nuclear installations, http://register.consilium.europa.eu/pdf/en/09/st10/st10667.en09.pdf

[3] Communication from the European Commission to the European Parliament COM(2008) 776 – Update of the nuclear illustrative programme in the context of the strategic energy review