Towards a new interdisciplinary approach for Euratom research, innovation and education: impact on EU and non-EU countries

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Vers une nouvelle approche interdisciplinaire pour Euratom (recherche, innovation et formation): impact sur les pays de l' Union Européenne (UE) et en dehors

Dans un monde multiculturel, soumis à des changements rapides et plein d'incertitudes politiques et économiques (en particulier, en ce qui concerne l'énergie), la recherche, l'innovation et la formation (RIF) en fission nucléaire et radioprotection sont confrontées à de nombreux défis qui exigent une nouvelle approche interdisciplinaire. Dans l'UE, ces défis sont, par exemple, des percées technologiques pour les réacteurs du futur et/ou un engagement accru du public dans les décisions. Le but est de continuer à améliorer les applications de l'énergie de fission et des rayonnements ionisants pour le bien commun.

Dans le cadre du Traité Euratom, une nouvelle approche – ou une nouvelle gouvernance – se met en place pour développer et enseigner les sciences et les technologies nucléaires, plus à l'écoute des parties prenantes et visant à l'excellence scientifique, humaine et organisationnelle dans l' UE et en dehors de celle-ci. Comme il s'agit d'enjeux globaux, les programmes Euratom de RIF attachent une importance primordiale à la coopération en dehors de l'UE, en particulier, lorsque il s'agit de développer et partager des compétences en culture de sûreté et sécurité nucléaire de haut niveau.

Mots clés : Euratom; fission nucléaire et radioprotection; nouvelle approche; recherche, innovation et formation; interdisciplinaire; culture de sûreté; coopération internationale

Naar een nieuw interdisciplinair aanpak voor Euratom (onderzoek, innovatie en onderwijs): impact op de landen van de Europese Unie (EU) en buiten

In een multiculturele wereld, onderworpen aan snelle veranderingen en vol politieke en economische onzekerheden (met name wat betreft energie), worden onderzoek, innovatie en opleiding (OIO) in kernsplijtingsenergie en stralingsbescherming geconfronteerd met vele uitdagingen die een nieuw aanpak vereisen. In de EU zijn deze uitdagingen, bijvoorbeeld, technologische doorbraken voor nieuwe reactoren en / of verhoogde betrokkenheid van het publiek bij de besluitvorming. Het algemene doel is toepassingen van kernenergie en ioniserende straling voor het gemeenschappelijk belang voortdurend te verbeteren.

In het kader van het Euratom verdrag, is een nieuwe aanpak - of een nieuw bestuur – aan de gang om nucleaire wetenschappen en technologieën te ontwikkelen en te onderwijzen, dichter bij de belanghebbenden en met het oog op wetenschappelijke, menselijke en organisatorische excellentie in de EU en daarbuiten. Omdat het een wereldwijd probleem betreft, hechten Euratom OIO programmas het grootste belang aan samenwerking buiten de EU, met name wanneer het gaat om de ontwikkeling en het delen van competenties in cultuur van nucleaire veiligheid en beveiliging van hoog niveau.

Sleutelwoorden: Euratom; kernsplijtingsenergie en stralingsbescherming; nieuw aanpak; onderzoek, innovatie en opleiding; interdisciplinair; veiligheidscultuur; internationale samenwerking

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Abstract and key Messages

In a rapidly changing multicultural world full of political and economic uncertainties (notably regarding energy), research, innovation and education (RIE – Knowledge Triangle) in nuclear fission are faced with a number of scientific-technological and socio-political challenges that require a new interdisciplinary approach. In the European Union (EU), those challenges are, for example, breakthrough technological developments and enhanced public engagement aimed at continuously improving applications of nuclear fission energy and ionising radiation.

The main stakeholders of Euratom RIE programmes have developed a common approach regarding **needs, vision and implementation instruments**. Focussing on knowledge creation and competence building, the common approach of Euratom and nuclear fission stakeholders can be summarized as follows:

a) Analysis of needs of society and industry: e.g. what kind of knowledge, skills and competences should be taught in nuclear fission sciences in order to continuously improve sustainability, safety & reliability, socio-economics and proliferation resistance?
b) Convergence towards a common vision: e.g. continuously improving and sharing nuclear safety and security culture world-wide through a new type of governance for Euratom RIE, integrating expert, policy and public knowledge to support decision making processes
c) Development of common instruments: e.g. synergy of national and international (including Euratom) education and training (E&T) programmes for lifelong learning and cross-border mobility, thereby preparing a new generation of nuclear experts.

As a result, a new way of "developing / teaching science" is proposed, closer to the end-users' needs, with the aim of developing scientific, human and organisational excellence in all parts of the EU and beyond. International collaboration, in particular, has long been – and is still - at the core of EU programmes in nuclear energy, as it forms part of the 1957 Euratom Treaty under Chapter 10 ("external relations"). The EU cooperation in "the peaceful uses of nuclear energy" goes beyond its territory through a number of international *Euratom Fission Cooperation Agreements*: one of the main goals is to develop and share competences in safety and security culture world-wide, while preparing the next generation of experts in nuclear fission and radiation protection.

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1. Introduction: Drivers and Enablers for changes in Euratom Research, Innovation and Education (RIE) programmes

One of the main goals of the Euratom RIE programme[1], in compliance with the Euratom Treaty (1957), is to contribute to the sustainability of nuclear energy by generating appropriate knowledge (research and innovation) and developing the required competences (education and training /E&T/). This, of course, is being done in synergy with national programmes within the EU Member States (MS) and together with international organisations, such as IAEA (*International Atomic Energy Agency,* Vienna) and OECD/NEA (*Nuclear Energy Agency,* Paris).

The focus is on continuous development of a common nuclear safety culture, based on the highest achievable standards, as this is also one of the main lessons learnt from the "stress tests" (Section 2.2) conducted in all 131 nuclear power plants (NPP) in the EU following the Fukushima Daiichi accident (Great East Japan Earthquake, 11 March 2011, magnitude 9). Remember that these "stress tests" were defined by the European Commission (EC) as targeted reassessments of the safety margins of nuclear power plants and were developed by the European Nuclear Safety Regulators' Group (ENSREG).

In this paper, the emphasis is on nuclear fission energy and radiation protection and, in particular, on synergy between nuclear research, innovation and E&T (Knowledge Triangle), i.e.:

- research: knowledge creation, usually in RTD organisations (public and private)
- innovation: technological applications, in industry and services (energy and medical)
- E&T: knowledge transfer and competence building (at higher education level).

1.1 Drivers: EU policy (top down) and "end-user requirements" (bottom up)

The drivers for changes in the Euratom RIE programme are of two types: EU policy (covering many fields, top down) and "end-user requirements" (set out by the stakeholders, bottom up).

a. **EU policy** to improve synergy within the Knowledge Triangle (top down)

The "Europe 2020 strategy for smart, sustainable and inclusive growth" [2] was launched by the EC in 2010 as a set of seven "Flagship Initiatives" [3]. Of particular interest are the Initiatives regarding research, energy and education, discussed in dedicated EC Communications issued in 2010, 2011 and 2010, respectively:

- Research: "Innovation Union [4] - Turning ideas into jobs, green growth and social progress" COM(2010) 546 (Brussels, 6.10.2010) – this Communication lays down the general objectives and EU added value of "Horizon-2020 - The Framework Programme for Research and Innovation"

[1] EC DG Research and Innovation /RTD/ Euratom - http://ec.europa.eu/research/energy/euratom/index_en.cfm
[2] *Europe 2020 strategy* - http://ec.europa.eu/europe2020/index_en.htm
[3] Flagship initiatives: http://ec.europa.eu/europe2020/Europe-2020-in-a-nutshell/flagship-initiatives/index_en.htm
[4] *Innovation Union* - http://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication_en.pdf

- Energy: "Resource-efficient Europe [5] - Towards a resource-efficient, low-carbon economy" COM(2011) 21 (Brussels, 26.1.2011) - this Communication is a confirmation of the three pillars of the EU Climate Change and Energy Policy (i.e. sustainability, security of supply, competitiveness)

- Education: "An agenda for new skills and jobs" [6] - "A European contribution towards full employment" COM(2010) 682 (Strasbourg, 23.11.2010) - this Communication discusses, in particular, EU strategies and instruments to foster lifelong learning and cross-border mobility.

As a result of the above Flagship Initiatives in the context of "*smart, sustainable and inclusive growth*", the EC is proposing a number of RIE actions related to energy technologies under the Horizon-2020 programme (2014-2020) [7].

b. **End-user requirements** of various types for Euratom RIE (bottom up)

Here is a non-exhaustive list based on the conclusions of the 2013 Symposium on Nuclear Fission Research for a low carbon economy, co-organised by the EC and the European Economic and Social Committee /EESC/ (Brussels, 26-27 February 2013) [8]. Of particular interest is the background document of this 2013 Symposium: the "*2012 Interdisciplinary Study - Benefits and limitations of nuclear fission for a low carbon economy: Defining priorities for Euratom fission research & training (Horizon 2020)*" that was launched in April 2012 upon request of the Council (Council meeting of 28 June 2011) in view of their Decision on Euratom Horizon-2020.

End-user requirements of scientific-technological type:

- continuous improvements in (1) Sustainability (e.g. minimise volume, heat and radio-toxicity of waste + efficient resource utilisation); (2) Safety & Reliability (e.g. deterministic and probabilistic assessment methods + nuclear safety culture) / research related to (1) and (2) has always been at the heart of Euratom programmes
- continuous improvements in (3) Socio-economics (e.g. total social costs of energy + public engagement in decision making); (4) Proliferation resistance and physical protection (e.g. protection against threats of mass destruction and radiological terrorism) / research related to (3) and (4) requires a comprehensive approach covering political, legal and technical issues
- towards better scientific support for Euratom regulations (e.g. regarding standards for radiation protection safety and nuclear safety); multi-sectorial approach (e.g. integration of nuclear generated electricity into smart grids); emphasis on common nuclear safety and security culture across the EU, based on technical, human and organisational excellence.

End-user requirements of socio-political type:

[5] *Resource efficient Europe* - http://ec.europa.eu/resource-efficient-europe/
[6] *An agenda for new skills and jobs* - http://ec.europa.eu/social/main.jsp?catId=958&langId=en
[7] Horizon-2020 RTD Framework Programme - http://ec.europa.eu/programmes/horizon2020/en/
[8] 2012 Study: http://www.eesc.europa.eu/?i=portal.en.events-and-activities-symposium-on-nuclear-fission-forum

- sustainable solutions to (1) possible shortages of nuclear skilled professionals and ageing workforce; (2) challenges requiring decisions over long time scales ("from cradle to grave *may exceed 100 years*") and amid tough world-wide competition
- a new way of "developing / teaching" nuclear science (new European governance) in order (1) to re-build public confidence regarding fission technologies and (2) to provide support to develop robust, equitable and socially acceptable energy systems
- towards a common language between the worlds of education and of work, using EU tools for E&T (e.g. Bologna 1999 process for students and Copenhagen 2002 for professionals) and taking into account new sociological characteristics (e.g. "X" and "Y" generations).

1.2 Enablers: European Technological Platforms and authoritative expert associations

The enablers for changes in the Euratom RIE programme are principally the *European Technological Platforms* (ETP) [9] and a number of *authoritative expert associations* [10] as well as national and Euratom RIE programmes in nuclear fission and radiation protection.

The ETPs bring together the main stakeholders in Euratom RIE, namely:

- research organisations (e.g. public and private sectors, industrial and radio-medical)
- systems suppliers (e.g. nuclear vendors, engineering companies, medical equipment)
- energy providers (e.g. electrical utilities and associated fuel cycle industry)
- nuclear regulatory authorities and associated technical safety organizations (TSO)
- higher education and training institutions, in particular universities
- civil society (e.g. policy makers and opinion leaders), interest groups and NGOs.

The *European Technological Platforms* and *authoritative expert associations* play an increasingly important advisory role in Euratom RIE programmes (see new governance in Section 4). In this context, the main stakeholders in Euratom RIE programmes discuss common needs, vision and implementation instruments. This common approach is described in a series of guidance documents, entitled: "*Vision Report*", "*Strategic Research* and *Innovation Agenda"* and "*Deployment*

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[9] List of *European Technological Platforms* (reactor safety, geological disposal, emergency, radio-ecology, etc)
- SNE-TP = "*Sustainable Nuclear Energy Technology Platform*" - http://www.snetp.eu/
- IGD-TP = "*Implementing Geological Disposal of Radwaste TP*" - http://www.igdtp.eu/
- ENEF = "*European Nuclear Forum Energy*" - http://ec.europa.eu/energy/nuclear/forum/forum_en.htm
- NUGENIA = *NUclear GENeration II & III Association* (1921 Belgian law) - http://www.nugenia.org/
- NERIS = *"European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery"* (established in June 2010) - http://www.eu-neris.net/
- ALLIANCE = *European Radio-ecology Alliance* (since October 2012) - http://www.er-alliance.org/
- EurADOS = *European Radiation Dosimetry* Group in medical and industrial applications
- http://www.eurados.org/en

[10] List of independent authoritative expert associations ("stress tests", radiation protection, low dose impact)
- ENSREG = "*European Nuclear Safety Regulators Group"*
- http://ec.europa.eu/energy/nuclear/ensreg/ensreg_en.htm
- WENRA =*Western European Nuclear Regulators Association*/ - http://www.wenra.org/
- HERCA = "*Heads of European Radiological protection Competent Authorities Association*"
- http://www.herca.org/index.asp
- MELODI = "*Multidisciplinary European Low Dose Initiative*" - http://www.melodi-online.eu/

Strategy". These documents are particularly useful for understanding the objectives set by the main stakeholders, and subsequently for enabling the EC, together with the research communities concerned, to set programmatic priorities.

2. International collaboration in nuclear safety and security culture

2.1 Instrument for Nuclear Safety Cooperation (INSC) and Instrument for Stability (IfS)

International collaboration (i.e. outside the EU) has long been – and is still - at the core of EU activities in nuclear energy research and training, as it forms part of the 1957 Euratom Treaty under Chapter 10 ("external relations"). A number of *Euratom Fission Cooperation Agreements* have indeed been signed to support scientific collaboration and technical exchanges in fission research: USA (DOE) in 2003 and (NRC) in 2009, Canada (AECL) in 1998; Japan in 2006; China (MOST) in 2008; Russian Federation (Rosatom) in 2002; Ukraine in 2002; Argentina in 1997; Australia in 2012; Kazakhstan in 2003 and Uzbekistan in 2003.

At global level, the EU cooperates beyond its territory with nuclear safety and security programmes. This work is mainly conducted by DG DEVCO (*Development and Cooperation - EuropeAid*) [11] which also fosters nuclear regulatory training. Remember the past TACIS Programme ("*Technical Assistance* to *the Commonwealth of Independent States*" / Former Soviet Union): a total of Euro 1120 million (including 226 for Chernobyl Funds) was spent on safety and (*Radiological* and *Nuclear)* security during the period 1991 - 2006.

Under the *Instrument for Nuclear Safety Cooperation (INSC)* [12], the EU has established cooperation with more than 20 countries world-wide. The specific objectives fixed by EU Council and Parliament to world-wide cooperation under the INSC are as follows:

a) promotion of an effective nuclear safety culture and governance, and implementation of the highest nuclear safety standards and radiation protection
b) responsible and safe management of spent fuel and radioactive waste, decommissioning and remediation of former nuclear sites and installations in third countries;
c) establishment of frameworks and methodologies for the application of efficient and effective safeguards for nuclear material in third countries.

The INSC also supports projects with the IAEA, and contributes towards completion of the Chernobyl projects through the Chernobyl Funds (*Chernobyl Shelter Fund /CSF/ and Nuclear Safety Account /NSA/*) managed by the *European Bank for Reconstruction and Development* (EBRD). INSC actions in E&T are usually of the *Tutoring & Training* type (T&T) [13], i.e. customized tutoring is

[11] DG DEVCO / Energy / nuclear safety - http://ec.europa.eu/europeaid/what/energy/nuclear_safety_en.htm
[12] Website of "European External Action Service" - http://eeas.europa.eu/nuclear_safety/index_en.htm
[13] DG DEVCO project coordinated by ENSTTI (January 2012 – December 2015) is an example of T&T
- "*Training and Tutoring for experts of the Nuclear Regulatory Authorities and their Technical Safety Organisations for developing or strengthening their regulatory and technical capabilities*"
- http://www.enstti.eu/index.php?option=com_content&view=featured&Itemid=214

offered for educating both young and experienced experts based on real day-to-day work, thereby significantly increasing the level of knowledge, skills and competences of students and tutees, and generating opportunities for networking.

Also worth mentioning is the financial and political *Instrument for Stability* (IfS) [14] which supports, inter alia, CBRN (*Chemical, Biological, Radiological* and *Nuclear)* risk mitigation activities. Mitigation of CBRN threats (security against weapons of mass destruction) is conducted, in particular, in the context of UNSC Resolution 1540 (April 2004). The objective fixed by the EU Council and Parliament to world-wide cooperation under the IfS is three-fold:

a. respond to urgent needs due to political instability or a major disaster;
b. build conditions for long term stability in particular by addressing major risks and threats that prevent political security and economic development (e.g. terrorism, organized crime, illicit trafficking, chemical-biological-nuclear risks);
c. participate in the crisis management cycle by supporting Common Security and Defence Policy operations.

One of the initiatives of the IfS is the setting up of a network of "*Centres of Excellence*": the aim is to mitigate CBRN risks of criminal, accidental or natural origin by promoting a coherent policy, improving coordination and preparedness at national and regional levels and by offering a comprehensive approach covering legal, scientific, enforcement and technical issues. As far as biological threats of natural origin are concerned, remember the human pandemic of Influenza A ("Swine Flu") that has afflicted the world in 2009 – 2010, causing more than 100 000 fatalities, mostly in Africa and Southeast Asia – this is known as H1N1 virus, which caused also the Spanish Flu in 1918 (Source: *Wikipedia "2009 flu pandemic"*).

There is of course synergy between the two instruments INSC and IfS: the common aim is to promote globally a high level of nuclear safety and radiation protection and to foster the application of efficient and effective safeguards of nuclear material (security).

2.2 "Stress tests" - targeted reassessments of the safety margins of nuclear power plants

It is worth recalling that the "stress tests" [15] (mentioned in Section 1) have been instrumental in boosting international collaboration within and beyond EU borders. Remember that after the Fukushima Daiichi accident, the European Council requested on 24/25 March 2011 that the safety of all EU nuclear power plants should be reviewed, on the basis of a comprehensive and transparent risk and safety assessment ("stress tests"). These "stress tests" were defined by the EC as *targeted reassessments of the safety margins of nuclear power plants* and were developed by ENSREG [10].

[14] IfS for global security and development challenges - http://ec.europa.eu/europeaid/how/finance/ifs_en.htm
- *EU CBRN Risk Mitigation Centres of Excellence Initiative* - Strengthening health laboratories to minimize potential biological risks (together with World Health Organization) : http://www.cbrn-coe.eu/Home.aspx

[15] Final report on the Peer Review of EU Stress Tests", 26 April 2012 - http://www.ensreg.eu/node/407 and http://ec.europa.eu/energy/nuclear/safety/stress_tests_en.htm and http://www.ensreg.eu/EU-Stress-Tests

Reports were produced by the national regulators in the 14 EU Member States with NPPs and subsequently reviewed by Review Teams (peer review process set up by ENSREG). The ENSREG Summary Report [15] was endorsed on 26 April 2012 with the country-specific peer review reports attached to it. As soon as the peer review process started, the public and stakeholders were provided with an opportunity to engage in the "stress tests". In conclusion (EC Communication COM(2012) 571, dated 4 October 2012) [16], the stress tests have demonstrated that nuclear safety is an area where cross-border cooperation and action at EU level bring tangible benefits. Significant safety improvements have been identified in all participating countries. The total cost of the upgrades is estimated at some Euro 25 billion, averaging about Euro 190 million per reactor.

The stress test process, and particularly its peer-review component, could also serve as a benchmark or a model for other countries and the international community. Worth mentioning in this context is the major international effort dedicated to the understanding of what happened at the Fukushima Daiichi NPPs and how the subsequent response (e.g. legislative changes and dedicated research & development programmes) was organised at international level. The latter suggestion was developed by EC President Mr José Manuel Durão Barroso (length of term in office: 2004 – 2014) in his declaration "*EU Action on Nuclear Safety*" [17] at the Nuclear Security Summit in Seoul, South Korea, 26-27 March 2012. Here is an excerpt:

.... Safety, security and non-proliferation are absolute priorities for the European Union. ....

In the wake of the Fukushima tragedy, Europe has taken the lead in defining and carrying out comprehensive risk and safety assessments of all nuclear power plants in the EU. We are conducting these tough "stress tests" on the basis of an agreed methodology, which can serve as a model for our partners.

.... These stress tests are unique, in particular since all EU countries have agreed to subject their nuclear power plants to additional assessments, and because citizens and civil society organisations are involved in the process.
.... In the interest of a stronger global safety culture, the EC will actively share the results of the stress tests. And we encourage our international partners to do the same.
.... We should also agree that only the best available technologies will be used for nuclear construction. Power plants that will operate for the next 50 to 60 years must not use yesterday's technology.
.... We offer our stress test process as a starting point. We will also give financial support through the EU Instrument for Nuclear Safety Cooperation, which currently has an overall volume of half a billion Euros.
In short: The EU is totally committed to boosting nuclear safety and I urge the strongest possible, common and truly global approach. We all stand to benefit from such progress.

[16] EC Communication about stress tests - http://ec.europa.eu/energy/nuclear/safety/doc/com_2012_0571_en.pdf
[17] Europa Press Release Rapid - http://europa.eu/rapid/press-release_SPEECH-12-227_en.htm?locale=en

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3. Widening the scope of Euratom RIE programmes by including energy, environmental, economic and social sciences

In view of their decision on the Euratom part of Horizon-2020, the EU Council (Council meeting of 28 June 2011) requested that the Commission *"organise a symposium in 2013 on the benefits and limitations of nuclear fission for a low carbon economy. The symposium will be prepared by an interdisciplinary study involving, inter alia, experts from the fields of energy, economics and social sciences".*

As a consequence, the above *"2012 Interdisciplinary Study"* (mentioned in Section 1.1) was launched in April 2012. This study was composed of two parts: a scientific-technological and a socio-political part. The Terms of Reference were focused on answering "*why – and how to – continue developing research and training activities in nuclear fission and radiation protection at EU level ?*". The "*2012* Interdisciplinary *Study*" was published on the occasion of and presented at the above mentioned 2013 Symposium (Brussels, 26-27 February 2013). An *Ethics study* covering all energy sources was also conducted in this context and was published in the proceedings of the 2013 Symposium [8] as well as in a separate EC/EGE document [18].

3.1 "2012 Interdisciplinary Study": scientific-technological part (SET Plan and ethics)

A total of 10 external experts were hired to identify and discuss scientific-technological priorities for Euratom Horizon-2020. Ten topics were selected for this purpose (Topic 7 covering international aspects and Topic 10 being the Synthesis), pertaining to three domains:

- EU Energy Policy - 2 Topics, namely:

  (1) three pillars of the EU Energy Policy (sustainability, security of supply and competitiveness); (2) European Strategic Energy Technology (SET) Plan

- Euratom Treaty and other EU policies - 5 Topics, namely:

  (3) Research and Development; (4) Education and Training and Skills; (5) EU Nuclear Safety and Security Aspects; (6) People, quality of life and environment; (7) Safety and Security Culture beyond EU borders

- Principles of good governance - 2 Topics, namely:

  (8) Science based policies and nuclear safety and security legislation; (9) Ethics.

In Topic 1 ("three pillars of the EU Energy Policy"), for example, the following priorities were proposed for Euratom RIE in nuclear fission and radiation protection:

- *Nuclear has ample capability to contribute to the three EU energy policy pillars simultaneously, certainly with more research and innovation:*

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[18] "*Ethical framework for assessing research, production, and use of Energy*" (Ethics Opinion n°27), 16/01/2013 BEPA/EGE study - http://ec.europa.eu/bepa/european-group-ethics/docs/publications/opinion_no_27.pdf

- *Nuclear is CO_2 free, if using a good fuel cycle; but its safety record has received a serious dent. Waste management and proliferation controls should be further improved. Better understanding of low-dose effects of radiation could ameliorate its reputation and acceptability.*

- *Security of supply is offered by resource availability (possibly using fast reactors), stable but dispatchable electricity production facilities capable of load following and large turbine-generators providing inertia to the system, permitting reactive power control for voltage stability.*

- *Nuclear leads to cheap decarbonisation, if it can keep its investment and operational costs low. Future load following, however, must be examined as an important issue."*

3.2 Socio-political part (nuclear governance) and recommendations to the EU Council

To set the socio-political scene of the Study, a total of 16 external experts were consulted to discuss questions pertaining to three domains, namely: decision making; risk governance; Euratom research and training. Civil society was also represented (including interest groups and non-governmental organisations /NGOs/) as follows: (1) by EESC which was co-organising the subject "2013 Symposium" with the EC; (2) by socio-political experts, some of them belonging to the *European Technological Platforms* or *authoritative expert associations*.

Out of the general recommendations (ten in total) issued by the Study and the subsequent Symposium, clear objectives are given for Euratom RIE programmes, e.g.:

- towards more science-based support for EU energy policy, with emphasis on *access rights, security of supply, safety, and sustainability* of energy (“Ethics Opinion no 27”)
- towards new and emerging technologies not only to support nuclear safety and security aspects but also to develop innovative areas such as nuclear medicine
- towards more active participation in the changing research and innovation scene world-wide, through international partnerships wherever there is advantage for the EU
- towards a world-wide common nuclear safety and security culture, based on the highest achievable standards related to scientific, human and organisational aspects [19]
- towards more inter-sectorial and inter-disciplinary programmes (e.g. scientific-technological and socio-political sciences) including new ways of engaging the public
- towards the creation and transfer not only of knowledge but also of skills and competences, taking advantage of instruments developed by EU and national policies.

Widening the scope of Euratom RIE programme, including energy, economics, environmental and social sciences, is particularly important. As a result, a new type of governance for Euratom RIE

[19] Safety culture is in fact an issue of common interest in many power generation organizations, as discussed in the already mentioned “Ethics Opinion no 27” (p 59) – Section 3.6.4 Safety:

“*Reducing the risks down to purely technical aspects would not fulfill the requirement for an integrated approach and comprehensive assessment. Consequences in terms of the environment and health should receive the same amount of attention as the cultural, social, economic, individual and institutional implications. A **safety culture** embraced by governments and operating organizations is necessary in the production, storage and distribution of energy in maintaining a low level of risk.”*

programmes is under development, integrating local, national and European decision levels while involving key non-technical and technical dimensions (next Section 4).

4. Governance: openness, participation, accountability, effectiveness and coherence

The EC has established its own concept of governance in the White Paper on European Governance issued in 2001, in which the term "European governance" refers to the rules, processes and behaviour that affect the way in which powers are exercised at European level, particularly as regards openness, participation, accountability, effectiveness and coherence. These five "principles of good governance" reinforce those of subsidiarity and proportionality (see also Laeken European Council of 14 and 15 December 2001 - Laeken Declaration on the future of the Union). These principles are meant to inspire all EU policies and actions, including in the nuclear domain (see DG ENER website dedicated to "*Towards a European Governance applied to nuclear issues*" [20]).

It should be stressed that there are many definitions and interpretations of “governance principles” amongst the Member States. Here is the definition from the above *White Paper*:

- Openness. The Institutions should use a language that is accessible and comprehensible for the general public.
- Participation. Improved participation is likely to create greater confidence in the end result and in the Institutions which deliver policies.
- Accountability. The Institutions must explain and take responsibility vis-à-vis those affected by their decisions or actions.
- Effectiveness. Policies must be effective and timely, delivering what is needed on the basis of clear objectives and an evaluation of future impact.
- Coherence. Coherence requires political leadership on the part of the Institutions to ensure a consistent approach within a complex system.

This development of a new governance structure is aligned with what happens in other EU and international institutions. Consultative bodies of the European Union such as the European Economic and Social Committee (EESC) [21] or the Committee of the Regions (CoR) play a key role in this process. The EESC represents civil society and its various stakeholders, while the CoR is the voice of local and regional authorities in Europe. For example, the EESC mission statement reads: “Committed to European integration, the EESC contributes to strengthening the democratic legitimacy and effectiveness of the European Union by enabling civil society organisations from the Member States to express their views at European level”.

The various “freedoms” within the EU are worth being discussed in this context. The Green Paper entitled “*The European Research Area (ERA): New Perspectives*” (April 2007) provides the outline of what is needed to introduce a “fifth freedom” - that of the “*movement of knowledge*”. The ERA is based on the internal market in which researchers, scientific knowledge and technology circulate freely. This would complement the four freedoms enshrined in the Treaty, protecting the free movement of *goods, services, capital* and *labour*.

[20] European legislation and International Conventions - http://ec.europa.eu/energy/nuclear/governance_en.htm
[21] EESC, a bridge between Europe and organized civil society - http://www.eesc.europa.eu/

Remember that the EU is a community of shared strong values. In this context, ethical considerations are of course particularly important. The concept of "*Sustainable Development*" (referring to both intergenerational sustainability and poverty eradication in the world) was first developed in the famous G H Brundtland Report "*Our Common Future*" (World Commission on Environment and Development, United Nations, 1987). Worth recalling in this context is the "precautionary principle" which is a "general principle of EU law" (Lisbon Treaty / Art. 191).

Fission technologies can be transmitted to the next generations only within the framework of a responsible strategy regarding waste management and/or recycling of fissile and fertile matters. This is in line with the IAEA statement: "*any use of nuclear energy should be beneficial, responsible and sustainable, with due regard to the protection of people and the environment, non-proliferation, and security*" [22].

It is worth recalling the authoritative Ethics report ("Ethics Opinion n° 27"), issued on 16 January 2013, by the European Group on Ethics in science and new technologies (EGE) and published together with the "2012 Interdisciplinary Study" (see Section 3), entitled: "Ethical framework for assessing research, production, and use of Energy" [18]. The EGE is a team linked with the Bureau of European Policy Advisers (BEPA), reporting directly to the President of the EC. The EGE was asked by President J.M. Barroso on 19 December 2011 to contribute to the debate on a sustainable energy mix in Europe by studying the impact of research into different energy sources on human well-being. In their conclusions, the EGE recommends achieving a fair balance between four criteria - access rights, security of supply, safety, and sustainability - in light of social, environmental and economic concerns. Recommendations are also made regarding "educational projects" related to "the responsible use of energy" (excerpt in footnote[23]).

One of the most recent applications of good governance by the EC in the nuclear domain (in particular, regarding openness and participation) was the organisation of the "Stress Tests" in March 2011 (details in Section 2.2), which produced, inter alia, high-level recommendations that have been introduced in the revised Euratom Safety Directive (Directive 10562/14 - Brussels, 30 June 2014), such as:

- public engagement (Article 8, dedicated to "*Transparency*"): *"1. Member States shall ensure that necessary information in relation to nuclear safety of nuclear installations and its regulation is made available to workers and the general public, with specific consideration to local authorities, population and stakeholders in the vicinity of a nuclear installation. …………4. Member States shall ensure that the public shall be given the appropriate opportunities to participate effectively in the decision making process relating to the licensing of nuclear installations, in accordance with relevant legislation and international obligations."*

[22] *Nuclear Energy Basic Principles*, IAEA NUCLEAR ENERGY SERIES No. NE-BP, December 2008 - http://www-pub.iaea.org/MTCD/publications/PDF/Pub1374_web.pdf

[23] Excerpt of «Ethics Opinion no 27» (p 63) / "Recommendations": «*4. enhance the awareness of citizens (starting from an early age) regarding the need to adopt new attitudes and lifestyles for the responsible use of energy by promoting and financing educational projects and awareness-raising initiatives …*»

- cross-border peer review: this mutual assistance process involves the national regulators within the EU (Chapter 2a *"Peer Reviews and Guidelines*").

Finally, the creation of *European Technological Platforms* (in particular, ENEF) [9] and *authoritative expert associations* [10] is aligned with the above "principles of good governance" (especially regarding "participation"). Other applications of those principles can be found in the areas of repository concepts for low and intermediate short-lived nuclear waste [24] or in Euratom regulations related to exposure to low doses of ionising radiation, where there is an increasing effort to better identify and understand societal expectations, needs and concerns. The related Euratom RIE projects involve, in particular, civil society (with significant representation of local communities, elected representatives, and NGOs, as well as social and natural scientists) together with traditional actors in the field such as industry (e.g. electricity generation or radio-medical equipment), public authorities, experts and research institutions.

5. Science for policy: towards robust, equitable and socially acceptable energy systems

In a rapidly changing multicultural world full of political and economic uncertainties, robust decision making (notably regarding energy mix scenarios) has become harder than ever. Moreover as far as long-term scenarios in the energy domain are concerned, it is necessary to make room for the unexpected: breakthrough technological findings or major political developments may redirect the course of history.

Remember, for *example*, that in the early 1900s, most physicists believed that physics was complete, described by classical mechanics, thermodynamics, and the Maxwell theory. In a famous address to the *British Association for the Advancement of Science* in 1900, Lord Kelvin (William Thomson) declared "*There is nothing new to be discovered in physics now. All that remains is more and more precise measurement*." Nobody anticipated the incredible journey of physics (and the many technological applications) in the next 100 years: for example, at that time, nothing was known about the structure of atoms and nuclei (only two fields were known: gravitation and electromagnetism).

Similarly, remember the *famous* prediction "The Stone Age came to an end not for a lack of stones, and the oil age will end, but not for a lack of oil.", pronounced in September 2000 by Sheikh Zaki Yamani, a Saudi Arabian who served as his country's oil minister from 1962 to 1986 (i.e. during the Arab oil embargo of the 1970's, OPEC crisis).

Science as support to policy decision making, is important, in particular, in the nuclear fission domain, as demonstrated, for example, in the following topics that are of interest to scientific and political decision makers:

- Best available science and public engagement in decision making for energy matters
- Risk governance and resilience for unexpected events (international concern).

5.1 Best available science and public engagement in decision making for energy matters

[24] Many Euratom research projects were devoted to transparent risk governance (e.g. RISCOM, COWAM, ARGONA): models were tested for risk decision making, based on the notions of analysis and deliberation.

Decisions about energy mix, that are based, for example, on advanced methods for life cycle and risk assessment, raise complex issues. An interdisciplinary approach is required with a language that should be understood by knowledgeable non-specialists. Breakthrough technologies to improve sustainability, safety & reliability, socio-economics and proliferation resistance (for example, nuclear fission reactor / burner systems of Generation IV type) are under development world-wide in public and private research organisations (including Euratom). Those breakthrough technologies are under discussion not only amongst scientists and engineers but also with regulators and civil society. Public engagement has indeed become crucial in nuclear decision making (see e.g. governance discussion in Section 4).

Good governance (based on the five above principles: *participation*, *openness*, *accountability*, *effectiveness* and *coherence*) is important, in particular, for decisions regarding nuclear fission applications that are expected to be based on strong values (including ethical principles). Equally important is the scientific foundation of decisions in regulatory or industrial organisations where advantage could be taken from closer collaboration with the research community. This is especially true whenever robust assessment techniques, confirmed facts and research findings are needed.

A new way of "developing / teaching science" (resulting, in particular, in guidelines how to select the Best Available Science) is emerging and being tested in research and innovation projects in many countries, with the aim of supporting the development of robust, equitable and socially acceptable energy systems. In this context, it is worth noting that some governmental and industrial organisations have developed an extensive science programme to support their decision making process – see, for example, the U.S. Environmental Protection Agency in the paper "Science at the EPA and the Establishment of Regulatory Science" [25].

5.2 Risk governance and resilience for unexpected events (international concern)

Risk governance is a systemic approach to decision making processes usually associated with natural and technological risks, with emphasis on mitigation and sustainability. If the risk is of a global, systemic nature, cohesion is necessary between countries and all stakeholders should be included (in particular, government, industry, research, academia and civil society). Risk governance deals with identification, assessment, management and communication of risks. Risk governance is in fact a difficult issue, not least because it includes societal objectives, ideology, beliefs, and numerous other non-scientific issues (in the strict sense of the word). Let us remind ourselves that change is accompanied by risk and that these are thus a permanent and important part of life. The willingness and capacity to take and accept risk is crucial for achieving social and economic development. Research and feedback experience have demonstrated that risks, and in particular those arising from power generation technologies, are often accompanied by potential benefits and opportunities. As a result of good governance, individuals and societies will be able to benefit from change while minimising the negative consequences of associated risks.

[25] "The need for regulatory science transparency at the EPA" - A. A. Moghissi, Institute for Regulatory Science, Committee on Science, Space, and Technology, U.S. House of Representatives, Nov 2011
http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/113011_Moghissi.pdf

Managing the unexpected is a tough challenge, in particular, in energy systems' technologies involving risks for population, environment or industrial installations. Safety, in particular, cannot be seen independently of the core process (or business) of the system, hence the emphasis on the ability to function under "both expected and unexpected conditions" rather than simply avoiding failure. This leads naturally to the concept of resilience to unexpected events. Here is a practical definition of resilience: "*The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions*" [26]. This definition also applies to an organisation if the word "organisation" is substituted for "system".

6. "Euratom Fission Training Schemes" for safety related jobs and functions

Continuous improvement of nuclear safety culture is a key objective of Euratom research and training in nuclear fission and radiation protection, keeping in mind that *safety is a process, not a state*. Especially after the Fukushima accident, it is ever more necessary to provide sufficient and adequate knowledge, skills and competences, thereby ensuring that international expertise is available to further improve global nuclear safety culture and, in particular, strengthen emergency preparedness and response.

As far as training is concerned, there are two types of initiatives in the Euratom RIE projects:

- interdisciplinary training workshops embedded in collaborative research projects, aiming to promptly transfer the latest scientific results to the research community
- *Euratom Fission Training Schemes* (dedicated E&T actions - see also ENEN association), using the instruments developed under the EU policy for *Education, Youth and Culture*.

Faced with the challenge of shortages of skilled professionals, the nuclear fission community has called for a steady upgrade of the level of knowledge, skills and competences while striving to attract a new generation of experts. The time horizon of the nuclear sector, however, is a big challenge. Remember that the life cycle of new NPPs covers a period of approximately 100 years, from design and construction to dismantling and "green field".

The "*Euratom Fission Training Schemes*" have been – and are still being – launched as "coordination actions" in specific areas where a shortage of skilled professionals has been identified. These actions quite naturally take into account a number of scientific-technological and socio-political "end user requirements" (Section 1.1). The emphasis is on safety-related jobs or functions in applications of nuclear fission energy and ionising radiation. These training schemes consist of portfolios of units of learning outcomes (made up not only *of knowledge*, but also of *skills and competences*) that are needed to perform jobs or functions identified as critical.

Knowledge is usually created in higher education institutions and in (private and public) research organizations. *Skills* and *competences* are usually the result of specific training and on-the-job experience, required to properly perform a specific job or function, usually to an established standard.

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[26] "Resilience Engineering" by E. Hollnagel (MINES_ParisTech, Centre for Research on Risk and Crises), 2006 http://www.gowerpublishing.com/pdf/SamplePages/Resilience_Engineering_in_Practice_Prol.pdf

Development and transfer of skills and competences – on top of knowledge – are of course essential, especially in jobs or functions where safety (and/or security) culture plays an important role [19].

To ensure the highest achievable standards for nuclear education and training at EU level and beyond, a non-profit association was formed in September 2003 (under French 1901 law): this is the *European* Nuclear *Education Network* (ENEN) [27]. This legal entity, located at CEA / INSTN Saclay-Paris, is composed of 64 members (universities, research organisations, industry) from 18 EU Member States + Switzerland, South Africa, the Russian Federation, Ukraine and Japan. The ENEN members are active, in particular, in Euratom Horizon-2020.

7. Conclusion: sharing Euratom achievements in scientific, human and organisational excellence between EU Member States and world-wide

Facts about energy in today's world, in particular when it comes to "competitive, secure and low-carbon EU economy", show that energy problems cannot be passed over lightly, and demand additional research and innovation efforts as well as a specific governance structure, integrating local, national and international decision levels. Energy problems should be looked at world-wide in the light of the economic, environmental and social requirements of the 21st century, integrating non-technical and technical dimensions.

Reminder. In the EU, the generation of electricity through nuclear fission is a fact of life. Nuclear power stations currently produce more than a quarter of the electricity and more than a seventh of the primary energy consumed. At the end of 2013, a total of 131 units were operable in 14 Member States. It is quite clear that nuclear fission will remain part of the energy mix for many decades to come. It should also be noted that, according to the IAEA, nuclear power is under serious consideration in over 45 countries which do not currently have it: these range from sophisticated economies to developing nations. The front runners outside the EU (i.e. Lithuania together with Estonia and Latvia; Poland) are Iran followed by the UAE, Belarus, Turkey, Vietnam and Jordan.

In the "2012 Interdisciplinary Study", an analysis was made of benefits and limitations of nuclear fission for a low carbon economy, involving, inter alia, external experts from the fields of energy, economics, social sciences and ethics. A number of drivers and enablers for changes in Euratom research, innovation and education were identified in this context. “End-user requirements” of scientific-technological and socio-political type are important drivers. The main enablers are the stakeholders – in particular, the European Technological Platforms and other authoritative expert associations - providing human and financial resources. Another important input to Euratom programmes is the set of conclusions drawn after the "stress tests" in all 131 NPPs in the EU (14 Member States concerned) following the 2011 accident in Japan.

Euratom is facing tough challenges related not only to research and innovation but also to programme management at EU level and beyond. Firstly, as far as research and innovation is concerned, an interdisciplinary approach is necessary to continuously improve the development of technologies and services following the key requirements of society and industry, i.e.: sustainability,

[27] *European Nuclear Education Network* (ENEN) - http://www.enen-assoc.org

safety & reliability, socio-economics and proliferation resistance. In applications of ionising radiation (e.g. in the medical field), the emphasis will be on better quantification of risks at low dose. Secondly, as far as programme management is concerned, a number of governance challenges remain open for Euratom, such as:

a. Better qualification of processes for creation and transfer of knowledge, skills and competences at EU level, thereby bridging the gap between generations and countries

Euratom E&T programmes should better integrate higher education institutions and "stakeholder" organisations (e.g. industry, research organisations, governmental bodies, etc.) in areas where human resources could be at risk. As a result, efficient schemes for Continuous Professional Development will continue to be developed under Euratom, consisting of portfolios of learning outcomes (made up not only of *knowledge*, but also of *skills* and *competences*), that will be recognised by employers across the EU, thereby improving *life-long learning* and *cross-border mobility* (Copenhagen 2002 process).

b. Develop scientific, human and organisational excellence, integrating non-technical and technical dimensions, with the aim of continuously improving safety culture competences

Integrating expert, policy and public knowledge is receiving increasing attention in the nuclear fission and radiation protection community (this is also a recommendation of the "*2012 Interdisciplinary Study*"). Wherever advisable, Euratom programmes should aim at a fair balance between scientific-technological and socio-political approaches, thereby coming closer to the needs of end-users, i.e. society and industry. The focus is on continuous development of a common nuclear safety and security culture, based on the highest achievable standards (this is also one of the main lessons learnt from the "stress tests" and shared world-wide).

c. Improve the scientific basis for the development of robust, equitable and socially acceptable energy systems, through a new way of "developing / teaching" sciences

There are many examples of application of good governance principles (i.e. openness, participation, accountability, effectiveness and coherence). For example, there is long-standing experience of public involvement in the areas of repository concepts for low and intermediate short-lived nuclear waste or in Euratom regulations related to exposure to low doses of ionising radiation. As a result, a new way of "developing / teaching science" is developing. The ultimate aim is to improve the scientific basis (using hard and soft sciences) needed for the development of robust, equitable and socially acceptable energy systems.

In conclusion, one of the objectives of Euratom Horizon-2020 is to widen the traditional scope of Euratom by including energy, socio-economics, environmental sciences and ethics. Euratom Horizon-2020, together with international and national programmes, will contribute to the emergence of a new generation of highly qualified experts in nuclear fission energy and radiation protection. This new generation is expected to solve problems related to energy, safety and security as well as health and environmental protection. The common ambitious objective is to continuously improve scientific, human and organisational excellence in the EU Member States and to share the Euratom achievements and experience world-wide.

Georges Van Goethem, October 2014
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