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IMPACT ASSESSMENT

Accompanying the

Communication from the Commission 'Horizon 2020 - The Framework Programme for Research and Innovation';

Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020);

Proposal for a Council Decision establishing the Specific Programme implementing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020);

Proposal for a Council Regulation on the Research and Training Programme of the European Atomic Energy Community (2014-2018) complementing the Horizon 2020 – The Framework Programme for Research and Innovation

Annexes

Annex 6: Euratom

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ANNEX 6: EURATOM

1. Procedural issues and consultation of interested parties

This annex contains supplementary information on the Euratom Research and Training Programme (2014-2018). Following the European Commission's decision of 29 June 2011 to bring together all EU research and innovation funding in a coherent, from-research-to-innovation overarching framework, the Euratom Research and Training Programme, hereinafter the Euratom Programme, is an integral part of 'Horizon 2020', the Framework Programme for Research and Innovation (2014-2020).

Commission's proposal for the Euratom Programme concerns research and training actions in the following fields: nuclear fission and radiation protection, nuclear fusion. The construction and related activities for ITER are subject to a separate proposal for a suplementary research programmme and therefore are not covered in this document.

For general information on organisation of the impact assessment exercise, including consultation and use of expertise please refer to the main report on the impact assessment for Horizon 2020. The following section provides specific information on consultation and expertise for preparation of the Euratom Programme.

Two workshops (consultations complimentary to the dedicated consultation on the basis of the Green Paper) have been organised with the objective of discussion the energy challenge of the future EU Research and Innovation Programmes with experts and representatives of governments. Both workshops covered nuclear and non-nuclear issues. The first workshop with non-governmental experts (from SET Plan technology platforms and research centres) took place on 23 June 2011. Stakeholders emphasised the substantial contribution of nuclear energy with regard to energy security and reducing greenhouse gas emissions as well as the leading position of European industry in nuclear energy. The second workshop with representatives from governments took place on 14 July 2011. Most delegations agreed on the importance of nuclear energy's contribution to the European Energy and Climate policy objectives.

Extensive evidence has been used for preparation of this report (for details please refer to specific footnotes):

- Euratom FP7 interim evaluations
- Quantitative input to the fusion part of the IA by an expert group appointed by the Commission
- Report of the Consultative Committee for Fusion (CCE-FU) "Strategic Orientation of the Fusion Programme" which details the main objectives of the fusion R&D programme and possible programme scenarios with different volume and pace of activities and consequences for the long term outlook of fusion research.
- Input from Euratom's Scientific and Technical Committee (STC)

2. Problem definition

2.1. Challenges for nuclear research and training

Nuclear energy is a mature low-carbon energy technology that is deployed at the industrial scale in many EU Member States[i]. Radiation is also used in industry and research, and in medical diagnostic and therapeutic techniques.

The main challenges as regards current nuclear technology in order for it to further contribute to competitiveness, security of supply and the decarbonisation of European energy systems are to ensure continuing high levels of safety, develop solutions for management of ultimate waste and maintain nuclear skills. Equally important is the need to ensure a robust system of radiation protection, taking into consideration the benefits of the uses of radiation in medicine and industry. In view of the increasing concerns about the risk of non-proliferation and the threat of nuclear terrorism it is also necessary to develop appropriate safeguards in order to assure nuclear security in Europe and worldwide.

Advanced nuclear technology has the potential to make a major contribution to the realisation of a sustainable and secure base-load energy supply for the EU in a few decades from now[ii,3]. The first steps to realise this potential are to demonstrate feasibility of fusion as a power source and to construct and operate next generation fast neutron reactor (FNR) demonstrator plants. Efforts to make advanced nuclear energy a reality can be justified by the availability of fuel (hydrogen and lithium in the case of fusion, or uranium and thorium with 50-100 times increased utilisation compared with present reactors in the case of FNRs – are inexpensive and readily available), no risk of severe accidents in the case of fusion, and limitation to the reactor site of the impacts of severe accidents in the case of FNRs. Fusion plants will produce only a limited amount of short-lived radioactive waste, and FNRs will be able to consume much of their own long-lived waste, though geological disposal of the ultimate waste will still be required to eliminate burdens on future generations.

To address these challenges and to bring benefits to the European citizens, a substantial research effort is needed to provide solutions for the following issues**:**

a) Nuclear safety of current and future power plants: Research will need to address issues of relevance for Europe arising from a detailed analysis of the Fukushima accident[iii], in particular any identified in the 'stress tests' being carried out in the EU[iv]. It is also important to maintain on-going research on issues of importance to the current fleet of reactors, in particular related to lifetime extensions and long-term operation. The current nuclear fleet in Europe is based mostly on Light Water Reactors (LWR) that have been in operation for about 25+ years on average. Current plans in most EU Member States are to extend their lifetimes on a case-by-case basis beyond 40 years, and possibly beyond 50 years. Key R&D issues are related to meeting safety requirements for long-term operation focussing on ageing of structures, systems and components. Other important issues are ageing mechanisms, monitoring and prevention and mitigation measures. Finally, research can also lead to improved efficiency of existing plants through reducing uncertainties in such areas as fuel performance[v]. The focus on safety will also need to extend to fundamental design work on next generation systems.

b) **Management of ultimate waste:** As indicated in the Commission's revised draft proposal for a Council Directive on the Management of Spent Fuel and Radioactive Waste[vi], all EU Member States produce radioactive waste, which is generated by civil nuclear power and radioisotope applications in medicine, industry research and education. More than half of Member States have accumulations of spent nuclear fuel, or residues from the reprocessing of this fuel, as a result of the operation of nuclear power plants. The general principle is that those who benefit today from these activities should manage the resulting waste in a safe and sustainable manner. This is also the overwhelming view of European citizens[vii], whose acceptance of nuclear energy is also strongly correlated to the implementation of solutions to safely manage nuclear waste. The R&D work carried out over last three decades has confirmed that deep geological disposal is the most appropriate solution for long-term management of spent fuel, high-level waste, and other long-lived radioactive wastes[viii]. This scientific consensus now needs to be turned into an engineering reality, and this will be the focus of attention over the coming decade[ix]. In addition to the implementation of geological disposal of ultimate waste, it is of great importance to minimize upfront the waste production to the maximum extend. This may be done by developing specific working techniques, processes and procedures leading to waste minimization. For Minor Actinides contained in spent fuel, research in partitioning and transmutation need to be pursued to demonstrate the feasibility to reduce the lifetime and radiotoxicity of the ultimate waste.

c) **Education and training in nuclear field:** As a generation of nuclear physicists and engineers retires and a series of nuclear 'phase-out' policies in some Member States leaves a gap in new talent entering the workforce, education and training have become driving concerns for every sector in the nuclear field[x]. This is a crucial issue even for countries phasing out their nuclear programmes, as existing facilities need to be operated for at least the next 15 years. Nuclear expertise is also needed for all industrial and medical applications based on ionising radiations, as well as for decommissioning activities related to old nuclear installations. Maintaining knowledge in these disciplines, along with appropriate programmes of nuclear education and training, are essential prerequisites for a high level of nuclear safety and nuclear safety culture[xi].

d) **Next generation fission systems:** Today's light water reactor technology uses less than 1% of the energy content of the mined uranium, which limits the sustainability of nuclear energy to a few decades because of the finite nature of the world's uranium reserves[xii]. By contrast, fast neutron reactors can extract 50-100 times more energy from the same quantity of uranium, making nuclear much more sustainable[xiii]. Furthermore, fast reactors are able to produce far less high-level long-lived waste, with a lower heat load, thereby greatly facilitating the management in future geological repositories. However, many R&D challenges remain, for example to address cost competitiveness, enhanced safety and non-proliferation, requiring innovation both in reactor designs as well as fuel and fuel cycle technology[xiv]. Though next generation fast neutron reactors are not expected to be widely deployed commercially before 2040, prototypes and demonstrators need to be designed and constructed in the next decade to enable sufficient return from experience before commercial deployment. Similarly, work on advanced high and very high temperature reactors can lead to the development of cogeneration systems capable of providing low carbon process heat for many industrial processes. In parallel to these advances on so-called 'Generation-IV' systems, a broad-based programme of R&D is needed in key areas such as materials, numerical simulation and safety. In many of these areas there are important synergies with research on materials and technologies for fusion power plants.

e) **Nuclear safeguards and security:** Expansion of civil nuclear technology worldwide brings with it an increasing concern about the risk of nuclear non-proliferation and the threat of nuclear terrorism. Safeguards of sensitive nuclear materials which rely on profound knowledge and expertise will therefore necessitate continued research and innovation efforts at EU and worldwide level.

f) **Radiation protection**: Radiation protection research is particularly important in view of the rapidly growing use of radiation in medical diagnostic and therapeutic techniques, which is responsible for a significant rise in public exposure, especially at low doses[xv]. Further multidisciplinary research is needed to determine the mechanisms involved and to quantify the risks of latent cancers and vascular diseases at these low doses. Radiation Protection in emergency situations such as under accidental conditions on and off-site require continued attention and improvements.

g) **Move toward demonstration and feasibility of fusion as a power source** To demonstrate feasibility of fusion as a power source, research must be carried out using existing and future research facilities such as JET and W7-X. This will allow expanding the knowledge base and maximising the scientific output of ITER, a scientific experiment, moving beyond present understanding in the key areas of plasma physics and technology. To achieve this, the research programme must: (i) develop operational scenarios that will secure and even exceed the baseline performance, and (ii) ensure the rapid and efficient start up of future fusion facilities, and protect the investment by minimising the chances of unexpected technical problems that would delay exploitation or incur extra cost for these facilities.

h) **Prepare the future generation of fusion researchers and engineers:** For carrying out fusion research Europe must ensure that it will have a sufficient number of highly skilled professionals (operators of large fusion devices including ITER, fusion scientist, programme leaders and engineers for design and construction). Fusion research programme should encourage talented young scientists and engineers to develop their careers in Europe, and to ensure that Europe will have the necessary human resources to exploit ITER in an international and competitive environment, avoiding the risk of ceding the future leadership of fusion research to our international partners.

i) **Lay the foundations for fusion power plants:** While ITER is the major step towards demonstration of feasibility of fusion as a power source, it is also necessary to launch the preparations for a demonstration power plant (DEMO) to demonstrate the commercial generation of electricity using fusion. The challenge is to position Europe so that it can build rapidly on the results from ITER to move as quickly as possible to the demonstration power plant, retaining a significant share of the intellectual property of fusion technology.

j) **Involve industry more closely and promote innovation**: by integrating industry in the development of fusion power plant studies, enhancing the transfer of knowledge and creation of spin offs from the programme as well as developing the skills and capacities necessary for a European fusion industry of the future. Already, industry is deeply involved in the construction of ITER, particularly as a supplier of high-tech components. Fulfilling these contracts will involve the transfer to European industry of expertise and know-how built up over a long period in the European fusion programme. This will stimulate innovation and increase the competitiveness of European high-tech industry. To meet the challenges inherent in this process, the Commission has launched a Fusion Industry Innovation Forum bringing together representatives of major industries, fusion research institutes and the Commission.

2.2. What is the situation in the private sector?

Fission: The assessment of the corporate R&D investments in nuclear energy is based on a limited number of companies, reflecting the consolidated situation in this sector in Europe and worldwide. French companies (AREVA, EdF) largely dominate the total corporate R&D investments in nuclear fission. Corporate research into all nuclear fission-related aspects amounted to around €550 million in 2007, of which R&D investment in nuclear reactor technology may be in the order of €200 million (i.e. ca. more than one-third)[xvi]. More recent data on the true level of investments in nuclear R&D is not available. However, an order of magnitude estimate of corporate R&D investments can be derived from the 2010 EU Industrial R&D Investment Scoreboard[xvii], which shows that companies with substantial activities in nuclear sector (utilities and construction)[xviii] spent almost 1200 million Euro on R&D (for nuclear, reneweables and fossil sources) of which ca. 71% (852 million Euro) was spent by AREVA and EdF alone. The electricity industrial sector is described by the 2010 EU Industrial R&D Investment Scoreboard as a medium-low R&D intensity sector (between 1% and 2% of net sales is spent on R&D).

The main focus of R&D investment in the nuclear sector is lifetime extension of currently operating plants and, in countries where the political and societal climate is right, technology developments in evolutionary LWR technology linked with new build projects[xix]. The R&D efforts of the private sector are to a certain extent fragmented and often duplicated owing to the fact that European utilities operate in an increasingly competitive market.

Financing schemes for waste management are based on the "polluter-pays principle", often involving a small levy on the price of nuclear electricity. Either electricity utilities make provisions in their accounts or, increasingly, State-managed ring-fenced funds are established[xx].

The nuclear industry is currently not prepared to invest heavily in the development of Generation-IV reactors because this technology is still 20-30 years away from possible commercial deployment and as a result there is considerable political, regulatory and economic uncertainty. The public sector continues to have a role at the stage of pre-commercial research in advanced technology, also in a context of international cooperation (e.g. Generation-IV International Forum[xxi]), but industry will be expected to contribute much more significantly during the next stage in the development of advanced systems, beyond the design and construction of demonstration plants, entering into a First-Of-A-Kind commercial plants and further replication

Fusion: fusion energy R&D is funded only by the public sector: the private sector does not yet invest in fusion because the time horizon is too long (2040-2050)**.** The generation of electricity from fusion power requires the control and understanding of very complex physical processes which can only be achieved using large experimental infrastructures. Many scientific milestones have already been achieved, the most important of which is the controlled generation of fusion energy in the JET device in 1997[xxii]. While this was a significant marker on the path to commercial fusion power, it is still distant from commercial exploitation and therefore entirely supported by public funding. ITER will bring commercial fusion power a step closer, but it illustrates the timescales involved: the detailed ITER design, including necessary experimentation and component prototyping, took close to 10 years (followed by about 5 years of international negotiations on legal structures and siting) and the lifetime of the project is 30 years[xxiii]. Moreover, ITER is still an experiment and therefore carries the risk that it will not achieve all its aims. This risk has been mitigated by spreading the cost among seven partners in an international consortium, which also maximises the scientific and industrial expertise available to the project.

Private investment will be a necessary aspect of the demonstration fusion power plant (DEMO) which will follow ITER. By that stage the technology will have matured to a stage where industrial investment can take over the commercialisation of fusion power in the timeframe beyond 2050. Even though the private sector does not invest in fusion, it is involved in public procurements for fusion (ITER, JET and smaller fusion facilities), which brings mutual benefits (technology transfer, development of new products and new skills) [xxiv].

2.3. What is the situation in the public sector of Member States?

Fission and radiation protection: Member States contribute to research on issues of political and societal concern such as nuclear safety, radioactive waste management and radiation protection. This stems from the societal decision to exploit nuclear technology and the associated shared responsibility of the State with the license holder to ensure appropriate levels of health protection for workers and citizens. In particular, publicly funded research can ensure that an appropriate balance between the risks and benefits is maintained and that regulations neither unduly prevent exploitation of potentially beneficial technologies nor expose individuals to unjustified risks. However the available data demonstrate that these efforts are fragmented and underfunded in some areas (LWR, nuclear supporting technology, Generation-IV). In addition, research priorities differ between Member States, as demonstrated by a table below (latest available IEA data shown for Member States for which a breakdown is provided[xxv]):

Breakdown of budget for R&D in nuclear field *The most recent data available, million euro*								
	Germany 2009	**%**	**France 2008**	**%**	**Finland 2008**	**%**	**Belgium 2007**	%
Light-water reactors (LWRs)	21.1	50.2%	9.1	2%	0.3	3%	24.0	61%
Other converter reactors	0.0	0%	38.3	9%	0.0	0%	0.0	0%
Fuel cycle	10.7	25.4%	66.2	15%	2.3	25%	3.6	9%
Nuclear supporting technology	0.0	0%	316.1	71%	6.8	72%	11.8	30%
Nuclear breeder	0.0	0%	9.1	2%	0.0	0%	0.0	0%
Other nuclear fission	10.2	24.4%	7.0	2%	0.0	0%	0.0	0%
Total	42.0	100%	445.7	100%	9.5	100%	39.4	100%
Source: IEA								

The very rough estimate prepared on the basis of IEA data for the period 2000-2009[xxvi] shows that public R&D expenditure in Member States was focused on nuclear supporting technology (48% - this category of expenditure concerns nuclear safety, radiation protection and decommissioning, control of fissile materials), followed by the fuel cycle (32%) and R&D specifically related to light water reactors including safety and environmental aspects (11%). Expenditure that can be classified as Generation-IV (nuclear breeders, high temperature reactors, advanced gas cooled reactors) accounted for only about 7% (€43 million in 2007)

According to JRC report[xxvii], Member States' R&D investment in nuclear reactor R&D (reactor technologies and fuel cycle) amounted to around €253 million in 2007. This represents about 43% of the total estimated expenditure in all nuclear fission-related R&D (€587 million). Similarly to the situation in corporate R&D expenditure, public funding for R&D is largely concentrated within France. In 2007, France accounted for more than half of the total EU Member States public investment in nuclear-related research. This result is in line with France's large share of nuclear generating capacity in Europe, i.e. about 50%. Other Member States investing significantly in nuclear research included Italy, Germany and the Netherlands.

Fusion: R&D in fusion energy is fully publicly financed in Europe and all research activities are coordinated within the integrated European fusion programme[xxviii]. The total expenditure on fusion in 2007 and 2008 amounted to €582.48 and 607.24 million (direct expenditure of Member States 53% and 51% respectively with the remaining part funded by Euratom)[xxix].

The expenditure of Member States on fusion R&D in 2007 and 2008 is shown in the table below. Four EU Member States (Germany, France, Italy and UK) and Switzerland (a participant in the EU fusion programme since 1978) account for more than 80% of the overall expenditure, with Germany accounting for ca. 40%. Duplication and fragmentation of efforts of Member States is avoided by the fact that all national R&D programmes are coordinated through instruments of the European fusion programme (Contracts of Association and the European Fusion Development Agreement).

Expenditure of EU Member States and Switzerland on fusion R&D in 2007 and 2008				
Country	**2007 (mln EUR)**	**% of total**	**2008 (mln EUR)**	**% of total**
Austria (ÖAW)	3.3	1.1%	3.1	1.0%
Belgium (LPP ERM – KMS)	4.9	1.6%	5.5	1.8%
Bulgaria (BAS)	0.2	0.1%	0.5	0.2%
Czech Rep (IPP.CR)	3.1	1.0%	1.3	0.4%
Denmark (RISØ)	1.9	0.6%	1.8	0.6%
Finland (TEKES)	4.2	1.4%	2.8	0.9%
France (CEA)	45	14.5%	46.3	14.9%
Germany (IPP. FZJ. FZK)	120	38.6%	137.7	44.2%
Greece (HR)	1.2	0.4%	1.6	0.5%
Hungary (HAS)	1.2	0.4%	1.0	0.3%
Ireland (DCCU)	1.2	0.4%	1.1	0.4%
Italy (ENEA)	52.1	16.8%	41.3	13.3%
Latvia (UoL)	0.3	0.1%	0.6	0.2%
Lithuania (LEI)	0.1	0.0%	0.2	0.1%
Luxembourg (ME)	0.1	0.0%	0.0	0.0%
Netherlands (FOM)	11.3	3.6%	9.7	3.1%
Sweden	5.2	1.7%	4.3	1.4%
Poland (IPPLM)	1.6	0.5%	1.6	0.5%
Portugal (IST)	4.4	1.4%	4.8	1.5%
Romania (MEdC)	1	0.3%	1.0	0.3%
Slovakia (AECU)	0	0.0%	0.7	0.2%
Slovenia (MHEST)	1.2	0.4%	1.3	0.4%
Spain (CIEMAT)	11.5	3.7%	10.2	3.3%
Switzerland (CRPP)	13.2	4.2%	12.6	4.0%
UK(former UKAE. now CCFE)	22.6	7.3%	20.5	6.6%
TOTAL	**310.8**	100.0%	**311.4**	100.0%
Source: European Commission, 2011, Expenditure is not indicated for Estonia, Cyprus and Malta as fusion labs in these Member States are part of Finnish, Greek and Italian Association respectively.				

2.4. Why EU-level intervention is necessary?

The challenge of nuclear safety and diminishing nuclear skills in Europe can be tackled effectively by exploiting synergies between research efforts of Member States and the private sector, and between scientific disciplines and technological sectors. An EU-level intervention can strengthen the research and innovation framework in nuclear technologies and coordinate Member States' research efforts thereby avoiding duplication, retaining critical mass in key areas and ensuring public financing is used in an optimal way. An EU-level programme also take on the high risk and long-term R&D programme in fusion energy, thereby sharing the risk and generating a breadth of scope and economies of scale that could not otherwise be achieved.

Nuclear research is the only area of research that has a direct mandate in the treaties (Articles 2, 4 and 7, and also Annex 1, of the Euratom Treaty[xxx]). The European added value of nuclear research is explicit in the Euratom Treaty itself and the Commission has an obligation to put forward an R&D programme to complement those in Member States.

The justification for Euratom intervention is based mainly on the need to ensure high and uniform levels of nuclear safety in Europe.

In the area of lifetime extension, the main challenge for Euratom support is to ensure the availability and acceptance of standard tools and methodologies across Europe[xxxi]. Owing to the nuclear safety implications, it is unacceptable that plant lifetime extension decisions in one country are not based on the same criteria and techniques as in others. The aim of public intervention is to ensure consistency and harmonisation especially to guarantee high and uniform levels of nuclear safety. Funding on lifetime extension by the utilities themselves is often proprietary and at significantly higher levels than the public component.

The justification for Euratom intervention in the area of management of radioactive waste is similar to the case of nuclear safety and plant lifetime management. The issue of long-term management of waste is one of high public concern, and Euratom action ensures that a common European view on key issues related to long-term safety prevails, that harmonised standards and practices are put in place, and also that technology transfer takes place from the most to the least advanced Member States. This is particularly important in view of the recently adopted EU Directive on the management of radioactive waste that seeks to end 'wait and see' attitudes regarding waste management in some smaller Member States.

A similar approach is needed in the area of education and training. The role of the Euratom's action is to stress common programmes, transferability and mutual recognition of qualification and skills so that the nuclear sector and society as a whole benefits – again, the driver for this is the need to ensure high levels of nuclear safety and to promote an appropriate safety culture.

During the last 10 years, the Euratom programme has fostered greater cooperation between nuclear research and industrial actors[xxxii]. This has been largely through the establishing of broad-based 'technical forums' in key areas (and the defining of related Strategic Research Agendas, SRA), and the strengthening and focusing of Member States R&D efforts thanks to the overall framework provided by the SET-Plan. The establishing of SRAs and the implementation of the SET-Plan in the nuclear field has resulted in restructuring of the R&D activities in fission and cooperation in key R&D infrastructure projects. These efforts need to continue, encouraging true joint programming between Member States, the establishing of legal entities and public-private partnerships where necessary (in particular driven by industry as end-users), and the de-compartmentalisation of research sectors to maximise synergies between scientific and technological disciplines (not only between, for example, advanced fission and fusion but also between nuclear and non-nuclear energy).

2.5. What is the added value of nuclear research at EU level?

The European added value of the Euratom programme is demonstrated by the following achievements in increasing nuclear safety, concentrating Member States' R&D efforts and strengthening innovation:

a) **The Euratom R&D programme provides a flexible and effective instrument to support research in nuclear safety**. Although it is still too early to draw final conclusions from the Fukushima accident and the results of the nuclear stress tests in the EU, already the events in Japan are provoking a widespread re-assessment of nuclear safety in Europe. Initially this is concentrating on regulatory practice and demonstrating resistance to extreme external hazards, but there may be important implications for research. The Euratom programme is an appropriate instrument to coordinate and carry out the necessary activities. This was the case following the Chernobyl accident, with a substantial EU investment of EUR 40 million over 20 years in the PHEBUS programme (core melt experiments in controlled conditions) and Euratom funding in other areas such as emergency management and rehabilitation of contaminated territories. In fact, Europe is the only region of the world maintaining significant competences in the area of radioecology – the study of the impact of radioactive contamination on ecosystems in general. The project STAR[xxxiii], a Network of Excellence to ensure long-term sustainability of the radioecology research sector, was launched at the beginning of 2011;

following the events at Fukushima, discussions have already begun to add a Japanese partner in the consortium.

b) Action at European level (Euratom) can quickly **mobilise a wider pool of excellence, competencies and multi-disciplinarity** than is available at national level.

In the fission area, projects such as NULIFE (understanding of the factors affecting the lifetime of nuclear power plants), STAR (skills in radioecology), DoReMi (low dose research) and SARNET-2 (research on severe accidents in nuclear power plants) are ensuring that competences in key technical sectors can be pooled and retained in Europe, requiring the bringing together of expertise from many Member States, and the establishing of legal entities to ensure sustainability and long term access to research results.

The achievements of the fusion programme resulting from joint exploitation of JET, rely on the collective endeavours of researchers and engineers from all across Europe (about 350 persons per year), supported by Euratom funding for mobility. Euratom finances two mobility schemes, one used generally for short visits to JET and between Associations (ca. EUR 5 million per year) and the other aimed mainly at longer term participation in the collective exploitation of JET (stays up to 4 years).

c) Action at European level (Euratom) can help generate an **optimum programme of activities and maximise knowledge sharing** and information dissemination, lowering the overall costs of achieving a given objective.

The extensive network of collaborations between fusion laboratories (Associations) and the collective exploitation of JET help bring the best expertise to bear on all the research issues, and provide Europe-wide sharing of expertise. A growing majority of publications (about 57%) originate from the joint efforts of two or more laboratories in different Member States. These papers also have a higher than average number of citations.

Euratom projects in the field of Partitioning and Transmutation, from the EUROTRANS project in FP6 to those focused on the design of the MYRRHA facility, represent a comprehensive and integrated programme of research on Accelerator Driven System and related lead-cooled technology. This programme is also notable for the involvement of large numbers of PhDs and post-docs and the interaction with other research in Generation-IV systems. All this, including the decision by the Belgian Government to construct MYRRHA, would not have been possible without Euratom involvement.

d) Action at European level (Euratom) can have a **strong leverage effect on coordinating national efforts**, through the use of funding instruments that promote the European Research Area.

These effects are well demonstrated in the case of the **European fusion programme** where Euratom provides much less than half the funding of the participating laboratories, but is able to ensure strong coordination of their efforts: (a) national funding agencies accept a limitation of their independence by allowing the scientific assessment of the programme and proposals for its evolution to be done collectively by representatives of Euratom associated laboratories and Member States with strong input by the Commission; (b) all the significant fusion facilities have been built with financial support from Euratom, which requires that their operation be open to researchers from all the Association laboratories; (c) smaller associations can concentrate on scientific topics or subsystems for any device in Europe and make important contributions while still maintaining the visibility of their own identity; (d) in addition to formal training activities, the extensive exchanges of personnel between the Associations ensure a Europe wide dissemination of expertise; (e) in some cases the management of the programme of the facilities is shared with the other participating Associations.

Structuring effects of technology platforms / technical forums in fission R&D: All major stakeholders in fission and radiation protection research are now grouped in technical forums: SNETP, IGDTP and MELODI, thereby promoting strategic planning, sharing resources and even joint programming, with a strong participation of industry in the two former forums.

e) Action at European level (Euratom) can take on high risk, high cost, long-term programmes beyond the reach of individual Member States, **sharing the risk and generating a breadth of scope and economies of scale** that could not otherwise be achieved.

The scientific and technological feasibility of fusion will be demonstrated by ITER. This has to be done at very large scale and cannot be broken down into smaller projects that could be handled at national level. On this scale it is necessary to pool financial resources and scientific expertise, and to share risk, in an international cooperation. Together the 7 international partners (EU plus China, India, USA, Korea, Russia, Japan) will prove the feasibility of fusion as an energy source, and Europe as host will obtain the largest share of the economic and scientific benefits.

Another example is the Joint European Torus (JET) the world's leading fusion experiment, with a volume of fusion plasma about 10 times larger than that in any other fusion device, and a configuration and performance closer to that of ITER than any other device. The total expenditure for construction, upgrade and exploitation of this European facility during 1978-2010 amounts to ca. 2000 Million EUR. The majority of this funding has come from the Community budget, but there has also been strong support from the Member States. In particular, the construction and operation of JET has only been possible because of the pooling of scientific and industrial expertise from all the Member States. The contributions of JET to the development of fusion must not be underestimated: (a) it is the only current fusion device which can operate with the fuel mixture of genuine fusion reactors; (b) it holds all the records for peak and sustained production of controlled fusion power; (c) it is the most ITER relevant machine for studies in preparation for ITER technology and operations; (d) it is the only present fusion device in which the essential fusion technology of remote handling has been developed and used for major interventions; (e) it is the most useful experiment for the training of future operational staff for ITER.

The High Performance Computer for Fusion (HPC-FF) is a valuable new tool for the fusion programme. Fusion modelling requires powerful computer resources; increasingly realistic simulations that are able to take into account the full ITER plasma will be an essential tool for the safe and efficient operation of ITER. The HPC-FF computer, hosted and operated by the Jülich Supercomputing Centre at the Forschungszentrum Jülich fusion Association in Germany, is among the 30 most powerful computers in the world. Euratom capital investment amounted to around €7.4 million, while the total budget including the capital investment and exploitation over four years will be around €16.8 million, with contributions from the entire European fusion community.

f) Action at European level (Euratom) can help give credibility to the EU's long-range policies on energy and **increase the willingness of investors to release capital for projects with particular importance for nuclear safety or with long lead-times** and **significant technology and market risk.**

Project SARNET-2 is an excellent example of the leverage effect of EU funding – the total budget is €38M but the EU contribution is just €5.75M (i.e. 16% of total costs). The project will continue the efforts of a number of European R&D organisations, including safety authorities, industry and universities, to network their research capacities in the area of severe reactor accidents, thus enhancing the safety of existing and future nuclear power plants. This Network of Excellence defines joint research programmes and develops common computer tools and methodologies for safety assessment of nuclear power plants, and ultimately ensures sustainable integration of the key R&D organisations in this sector.

European Sustainable Nuclear Industrial Initiative (ESNII) constitutes one of the three technology pillars of SNETP and is moving forward with the design and construction of three fast reactor technologies of the next generation (Gen-IV). Euratom is co-funding cross-cutting topics and pre-commercial research, though national public and private investors will probably be responsible for funding construction of the demonstrator plants (ASTRID, MYRRHA and ALLEGRO).

The closer involvement of industry in fusion development has been launched by the establishment of the **Fusion-Industry Innovation Forum**. It will have an increased role in during future EU research programmes, especially in relation to preparation for the construction of DEMO. As well as providing the foundations for creating a strong fusion industry in the future, in the short term it will promote technology transfer and dissemination in order to maximise innovation.

g) In international cooperation, it makes it easier for our international partners to interact with a **single interlocutor** and build common actions.

In all matters concerning **ITER and the Broader Approach**, Euratom is the signatory of the agreements, and the Commission is the sole interlocutor for matters of governance. This is essential for such complex international projects. The Commission has also taken the responsibility for establishing **bilateral agreements with third countries** (especially the ITER partners), which provide an umbrella under which collaborative research of mutual benefit can take place with standardised provisions on, for example, intellectual property matters.

The Generation-IV International Forum (GIF) is fostering multilateral cooperation in research on next generation nuclear technology. Euratom and all major civil nuclear power programme countries are cooperating though the exchange of results on pre-conceptual design research on six advanced systems. All research stakeholders in Europe can benefit from Euratom membership of GIF, in particular by being a partner in a relevant Euratom FP project. The dialogue in the GIF is also helping to establish future partnerships for design and construction of demonstrator plants.

2.6. EU performance in nuclear research - comparison with USA and Japan

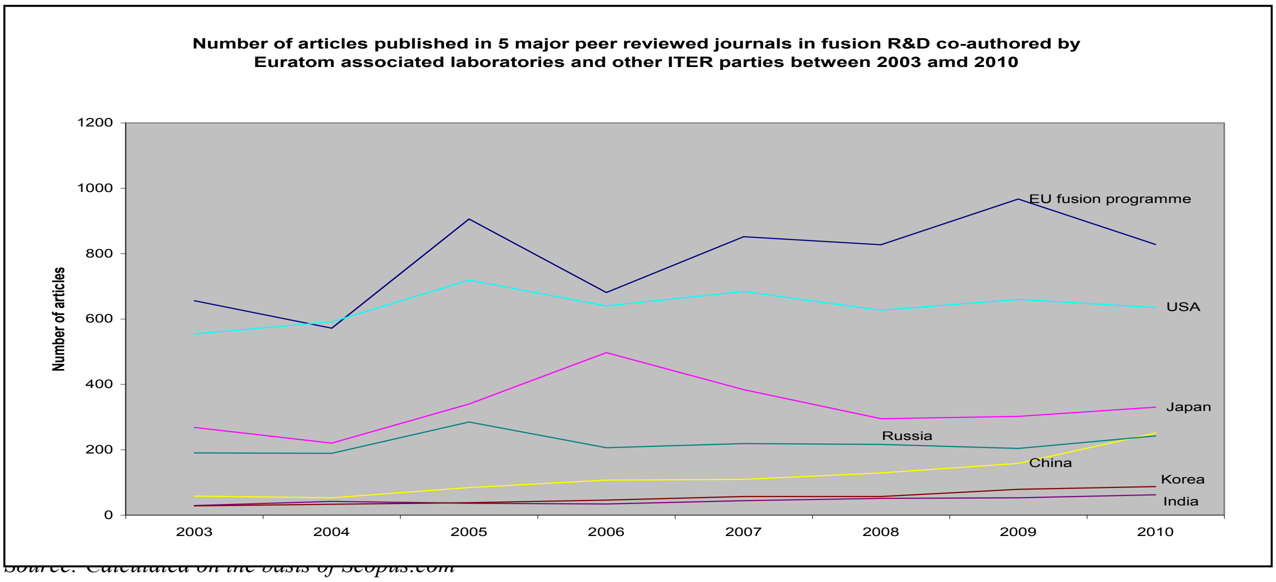
Fusion: Overall, the EU (Member States and Euratom) devotes the largest worldwide budget to fusion research (see table below) and dominates fusion science and technology.

Annual budgets for fusion energy research *estimates in million Euro,*					
	2007	**2008**	**2009**	**2010**	**2011**
EURATOM (1) (including ITER)	271.8	295.9	388.7	438.9	438.0
EU Member States (1)	310.8	311.4	About 300 million euro / year		
Total for Europe (1)	582.6	607.3	About 700 million euro / year		
USA(2)	232.2	215.1	355.4	321.3	307.5
Japan (2) (3)	115.9	150.5	152.7	N/A	N/A

Sources: European Commission, US Department of Energy, IEA
(1) Magnetic confinement R&D only
(2) Includes Magnetic confinement R&D and inertial confinement
(3) May not include all administrative and running costs.

Analysis of peer reviewed journals and citations show a strong leadership of the Europe in fusion R&D. **Europe through its fusion laboratories co-authored the largest number of articles published during the period 2003-10** in five international peer reviewed journals in the field of plasma physics and fusion[xxxiv], with an **average number close to 800 articles per year** (see figure below).

Europe's leadership in fusion is further underlined by the fact that **436 of most cited 1000 articles** published in these 5 journals were prepared on the basis of research co-funded by Euratom. **On average each of these 436 articles resulted in 25 citations** (similar to USA, 26, and better than Japan, 21) with the **best article yielding 141 citations.**



Source: Calculated on the basis of Scopus.com

Some countries like Russia and USA have fusion R&D programmes well established since the 1950s, while others such as China, Korea and India have developed more recently (1990s-2000s) in parallel to intensification of the ITER programme. All the ITER partners are pursuing the tokamak approach, but none have facilities comparable to JET. The rate of progression of Asia is fast and impressive and Europe will have to adapt its effort to this evolving situation in order to benefit from its past investments.

<u>Fission</u>: Recent data indicate that Europe spends less on fission R&D than USA and Japan (assuming that expenditure in 2009-2011 has remained at the 2008 level in the table below). The European R&D sector in fission is dominated by France and covers a wide range of activities in all relevant areas, though is particular strong in nuclear safety, geological disposal and radiation protection. Regarding research in advanced systems, the situation is less favourable, even despite projects such as ASTRID and MYRRHA. Annual figures collected by the Generation-IV International Forum (GIF, unpublished) show that Europe is investing similar amounts in pre-conceptual design research on advanced systems as other GIF members, but that Asia is much further advanced regarding development of demonstrator reactors, with high temperature reactors and sodium cooled fast reactors under construction in China, India and Japan, and Russia also advancing rapidly. These countries are also dominating the market for new build of current nuclear technology.

Annual budgets for research in fission and radiation protection *In million EUR*							
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
(1) Euratom budget	49.5	53.1	48.7	49.5	51.7	51.0	52.0
(2) EU Member States	598.8	577.6	585.9	514.0	N/A	N/A	N/A
Europe. Total (1+2)	648.3	630.7	634.6	563.5	N/A	N/A	N/A
USA	379.7	288.0	394.2	489.2	560.7	593.4	N/A
Japan	1981.6	1861.8	1880.4	1868.1	1835.5	N/A	N/A
Source: European Commission. IEA. US Department of Energy *IEA database is incomplete and does not cover all Member States (see footnote no. 33)*							

Europe's performance in the area of nuclear fission R&D can be measured in patents registered in the European Patent Office[xxxv]. For the period 1990-2008, the European industry and research sector (from 27 Member States) has been granted about 1164 patents (51% of all registered by EPO) in the field of nuclear reactors and nuclear power plants. Other major players are USA and Japan (37% and 11% respectively).

However, the majority of these patent applications concern current not future reactor systems. Without continued efforts in Nuclear Research and Innovation, ranging from present reactors to Generation III and IV, the EU will quickly loose its technological leadership since in other parts of the word, advanced reactor systems are under construction or already in operation.

3. Objectives for the future Euratom Research and Training Programme

In order to tackle the problems identified in section 2, it is important to clarify the objectives of Euratom's actions in the field of nuclear research and training.

The overall objective of the Euratom Research and Training Programme (2014-2018) will be to improve nuclear safety, security and radiation protection, and to contribute to the long term decarbonisation of the energy system in a safe, efficient and secure way. This shall reinforce the three objectives of "Horizon 2020" programme: strengthening excellence in the science base; creating industrial leadership and competitive frameworks; tackling societal challenges.

For the attainment of its objective the Euratom Programme shall strengthen the research and innovation framework in the nuclear field and coordinate Member States' research efforts, thereby avoiding duplication, retaining critical mass in key areas and ensuring that public funding is used in an optimal way. The Programme shall continue to promote the European Research Area and the further integration of new Member States and associated countries.

While it is for each Member State to choose whether or not to make use of nuclear power, the role of the Union is to develop, in the interest of all its Member States, a framework for supporting cutting-edge research on nuclear fission technologies, with special emphasis on safety, security, radiation protection and non-proliferation. In order to maintain the Union's nuclear expertise, the Programme shall further enhance its role in training.

The Commission proposed in a communication "A Budget for Europe 2020" (COM(2011) 500) that for projects such as ITER, where the costs and/or the cost overruns are too large to be borne only by the EU budget, the funding should come from outside the MFF after 2013. This will enable the EU to continue to fully meet its international commitments. Therefore ITER construction and related activities are not subject of the Euratom Research and Training Programme and a separate proposal for a supplementary research programme for ITER construction will be prepared.

In order to achieve the overall objective, the following specific objectives must be attained by **indirect actions:**

a) Support safe operation of nuclear systems;

Research to underpin the safe operation of reactor systems (including fuel cycle facilities) in use in Europe or, to the extent necessary in order to maintain broad nuclear safety expertise in Europe, those reactor types which may be used in the future, focusing exclusively on safety aspects, including all aspects of the fuel cycle such as partitioning and transmutation.

b) Contribute to the development of solutions for the management of ultimate waste;

Research activities on remaining key aspects of geological disposal of spent fuel and long-lived radioactive waste with, as appropriate, demonstration of the technologies and safety, and to underpin development of a common European view on the main issues related to waste management from discharge of fuel to disposal. Research activities related to management of other radioactive waste streams for which industrially mature processes currently do not exist.

c) Develop and maintain nuclear competences;

Promote training and mobility activities between research centres and industry, and support maintaining nuclear competences in order to guarantee the availability of suitably qualified researchers, engineers and employees in the nuclear sector over the longer term.

d) Foster radiation protection

Research will focus in particular on the risks from low doses (from industrial, medical or environmental exposure) and on emergency management in relation to accidents involving radiation, to provide a scientific basis for a robust, equitable and socially acceptable system of protection.

e) Move toward demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities

Support common research activities undertaken by members of the European Fusion Development Agreement to ensure the rapid start up of high performance operation of ITER including inter alia, the use of relevant facilities (including JET), integrated modelling using high performance computers, plus training activities to prepare the ITER generation of researchers and engineers.

f) Laying the foundations for future fusion power plants

Support for joint activities undertaken by members of the European Fusion Development Agreement to develop and qualify materials for a demonstration power plant requiring, inter alia, preparatory work for an appropriate material test facility and negotiations for the Union's participation in a suitable international framework for this facility.

Support for joint research activities undertaken by members of the European Fusion Development Agreement that shall address reactor operation issues and shall develop and demonstrate all relevant technologies for a fusion demonstration power plant. Activities include preparation of complete demonstration power plant conceptual design(s) and exploration of the potential of stellarators as a power plant technology.

g) Promote innovation and EU industry competitiveness

Implement or support a knowledge management and technology transfer from the research co-funded by this programme, including ITER, to industry exploiting all innovative aspects of the research. For the longer term, the Programme shall support the preparation and enhancement of a competitive nuclear industry, in particular for fusion through the implementation of a technology road map to a fusion power plant with active industrial involvement in the design and development projects.

h) Ensure availability of research infrastructures

Support construction, the use and continued availability of, appropriate access to, and cooperation between key research infrastructures within the scope of Euratom programme.

<u>**Direct actions by the Joint Research Centre** will contribute to the Euratom Programme's overall objective by attaining the following specific objectives:</u>

a) Improve nuclear safety including: fuel and reactor safety, waste management and decommission; and emergency preparedness;

b) Improve nuclear security including: nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics;

c) Raise excellence in science base for standardization;

d) Foster knowledge management, education and training

e) Support EU policy and legislation on nuclear safety and security

4. POLICY OPTIONS

The Euratom Research and Training Programme is an integral part of the Commission proposal for 'Horizon 2020' the Framework Programme for Research and Innovation. Therefore an analysis of general policy options presented in the main report on the impact assessment for the 'Horizon 2020' apply also to the Euratom Programme.

The following section provides a supplementary information and analysis of policy options (scenarios) for the fusion research programme.

Scenario 1 aims at the shortest path to demonstrate electricity production from a DEMO fusion reactor by 2040;

Scenario 2 takes full benefit of ITER exploitation but with a slower rate of progress on power plant related activities;

Scenario 3 curtails the research programme, delaying DEMO by more than 10 years and compromising the capability of EU industry to become a main actor in the eventual worldwide fusion energy market.

Evaluation of these scenarios is supplemented by the analysis of risks and benefits of fusion research.

5. ANALYSING THE IMPACTS AND COMPARING OPTIONS

5.1. Analysis of scenarios for fusion research

Given the potential of fusion to satisfy future energy requirements and assuming that it will have to take as soon as possible a substantial share of base-load electricity production in the future, it is appropriate to consider reaching the ultimate objective as quickly as possible with a **first scenario** requiring an increased level of activities and resources. This scenario assumes that an ambitious programme should be put in place to have fusion energy electricity in the grid from a demonstration reactor by 2040 and prototype power plants available by 2050. In-depth assessments by the fusion community have shown that this scenario requires the completion of the ITER construction and achievement of first plasma by 2020, followed by the start of Deuterium and Tritium operation by 2027. DEMO design by industry supported by the fusion community should start as soon as scientific results, materials and engineering data are available from ITER exploitation and from other complementary activities, probably a little before 2030. In addition to the present spectrum of research activities, the early implementation of two other projects with long lead-times is essential if such a rate of progress is to be achieved: the development and testing of "Tritium Breeding Modules" for tritium self-sufficient operation of fusion reactors (a TBM programme was established by the ITER Council in 2009 and TBMs will be tritium-tested in the ITER facility from 2027); and preparation for an ad-hoc fusion specific neutron source so that its construction could start by 2020. The first scenario would require a re-evaluation of current funding schemes and structure of the research programme in Europe and the way it is implemented, especially in order to favour more rapid industrial take-up of the technology

Pros: Demonstrating fusion energy potential to produce electricity by 2040 and putting power plants in the grid by 2050, maintaining EU leadership and optimally positioning EU industry to exploit the commercial potential.

Cons: High cost scenario during the period until 2020.

A second scenario assumes that fusion is less urgently needed to complement/substitute other energy sources. It partially omits / postpones some activities and generally has a lower level of activity during the period 2014-2020, postponing a number of developments beyond 2020 and implying acceptance of a longer timescale. As in first scenario, reassessment of the Euratom funding approach is necessary.

Pros: A level of activities maintaining the overall goal of the research programme, at an average cost until 2020 that may be comparable to the average level in FP7.

Cons: Higher risk than in the first scenario and the pace may be slowed down depending on capacity to address scientific/technical/industrial issues during development, and likely higher total cost to reach the ultimate objective owing to delays.

A third scenario implies a severe curtailment and/or postponement of R&D activities including for ITER systems (e.g. for heating systems, Test Blanket Modules) with the consequent risks and likelihood of delays in ITER construction and a slow start of its operation. In this scenario the EU fusion programme would essentially consist of the EU contribution (subject to separate decision) to the (likely delayed) ITER project accompanied by limited other fusion activities. The EU, which is the major contributor to the ITER project, would not reap the full benefits of its investment and the exploitation of the ITER facility would mainly benefit our international competitors. In addition, the EU's progress towards DEMO and fusion energy would be substantially delayed.

It should be emphasised that the most important part (and corresponding cost) of Europe's efforts to establish feasibility of fusion as a power source during the period covered by the 'Horizon 2020' will be, by far, the EU contribution to ITER construction (subject to separate decision on supplementary research programme). It appears therefore sound, subject to the availability and distribution of resources under Horizon 2020, to opt for the first scenario in order to have fusion energy available as soon as possible.

5.2. Where are the risks and benefits of future EU investments in nuclear research?

The main benefit of the fusion research is, in a very long term, to provide solutions for development of fusion as a viable alternative for a large scale and low carbon base-load energy source. The fusion programme proposed for 2014-18 will bring the following specific benefits:

- **Efficient operation of ITER:** the R&D programme will expand the existing knowledge and prepare staff to ensure that Europe will have the human resources to exploit ITER in an international and competitive environment;
- **Acceleration of development of fusion power plants –** in parallel to R&D for ITER, the programme will lay the foundations for fusion power plants by driving forward the significant physics and technology developments that are required.
- **Contribution to the EU competitiveness** – the body of expertise created in by the fusion research community, will provide immediate technology transfer benefits for industry and services[xxxvi].
- **Spin-off benefits of fusion research** – besides the promise of bringing sustainable energy supply in the future, fusion R&D is yielding additional societal benefits which should be taken into account in the allocation of public R&D funds[xxxvii]. Fusion research has pushed many of the cutting-edge technologies to new limits and in many cases innovative solutions to challenging problems have found applications far beyond the bounds of fusion (cooled high heat flux components in space applications, improvement of Magnetic Resonance Imaging (MRI), applications in brakes and clutches used in trains and motor racing)[xxxviii].
- **Reduction of risks regarding future exploitation of fusion energy** – research can further reduce economic, environmental and social risks (see table on the risks and benefits of fusion).

The main risk for fusion research is that it is still at the experimental stage and it may fail to deliver results i.e. demonstrate the feasibility of fusion as an energy source**.** Such a failure will result in economic loss in term of investments made and lost opportunities for using resources for other purposes.

5.3. Risks and benefits of fusion energy

The table below shows possible benefits and risks related to the eventual exploitation of fusion energy (summary of assessments made in numerous peer review journals and studies).

Risks and benefits of fusion energy	
Benefits	
Economic	– The scale and sustainability of fusion energy production will not be limited by fuels (deuterium and tritium) – High energy density and no major land use; – Possible source of stable base-load energy supply – Preliminary analyses based on set of assumptions indicate competitive costs of electricity from fusion
Environmental	– no CO_2 emissions from fusion operations, very low carbon emissions for the whole life-cycle; – The maximum radiological doses to the public arising from the most severe conceivable accident driven by in-plant energies would be well below the level at which evacuation would be considered and would be comparable to typical annual doses from natural causes. – After a few decades, the total radiotoxic potential of the activated material arising from the operation and decommissioning of the fusion plant will have decreased to a low value. All of this material, after remaining in situ for a few decades, may, if desired, be cleared or recycled, with little, or no, need for repository disposal. – No possibility for runaway reactions or meltdown, and much smaller quantities of highly radioactive material than in fission reactor. A Fukushima-type melt-down accident cannot happen in a fusion reactor. – Fusion has significant proliferation advantages compared to fission. Any illicit use of fusion neutrons for transmutation to produce fissionable materials would be easily detectable.
Social	– Important domestic added value (European technological leadership) – Negligible human health impacts
Risks	
Economic	– Fusion's role in the energy mix is very sensitive to the costs – Availability factor for future power plant – Fusion will be able to enter the market in the second half of the century if environmental constraints are applied consistent with a maximum atmospheric CO_2 concentration in the range of 550 to 650 ppm.
Environmental	The main nuclear risk associated with fusion is the use of tritium as fuel
Social	Need to teach society about new source of energy
Sources*: Final Report of the European Fusion Power Plant Conceptual Study (PPCS)* EFDA 2005; *Study on safety and environmental impact of fusion*, EUR (01) CCE-FU / FTC 8/5, EFDA April 2001; *Power plant conceptual studies in Europe*, D. Maisonnier, D. Campbell, I. Cook, Nucl. Fusion 47 (2007) 1524–1532; *Revised assessments of the economics of fusion power*, W.E. Han, D.J. Ward / Fusion Engineering and Design 84 (2009) 895–898, *Economically competitive fusion*, David J. Ward and Sergei L. Dudarev, December 2008, Materials Today, Vol. 11, No 12,	

6. EVALUATION AND MONITORING

To achieve the objectives set out in Section 3 it is vital to put in place an appropriate system for Euratom's programme evaluation and monitoring. The Euratom programme will follow key principles for the evaluation and monitoring presented in chapter 6 of the main report of the impact assessment of "Horizon 2020" Framework Programme for Research and Innovation.

To monitor progress specific indicators. Separate for direct and indirect actions, will be used.

6.1. Indicators for indirect actions

a) Support safe operation of nuclear systems;

Indicator: Percentage of overall programme funding going on projects likely to lead to a demonstrable improvement in nuclear safety practice in Europe.

Current: XX% (2011); Target: XX% (2018) *Data for this indicator will be provided later*

b) Contribute to the development of solutions for the management of ultimate waste;

Indicator: Number of geological repositories for spent nuclear fuel and/or high-level waste that are planned in Europe and for which a *safety case* has been prepared and construction application made.

Current: 0 (2011); Target: 3 (2018),

c) Develop and maintain nuclear competences;

Indicator: Training through research - number of PhD students and Post-Doc researchers involved in Euratom fission projects

Current: ca. 200 (total for 2006-2011); Target: 300 (total for 2014-2018)

Indicator: Number of fellows and trainees in the fusion programme

Current: on average 27 per year (2011); Target: 40 per year (2018)

d) Foster radiation protection

Indicator: Percentage of funding going on projects likely to have a demonstrable impact on regulatory practice regarding radiation protection.

Current: XX% (2011); Target: XX% (2018) *Data for this indicator will be provided later*

e) Move toward demonstration and feasibility of fusion as a power source by exploiting existing and future fusion facilities

Indicator: Number of publications in high impact journals

Current: ca. 800 (2010); Target: Maintain current levels (2018).

Description of the indicator: Source of data – Scopus database. Please note that with the fusion programme's emphasis shifting from research to technology development this indicator may be lower in the future. Indicator concerns articles where at least one contributing author is from the European fusion laboratory participating in the Euratom Programme. It is calculated on the basis of 5 most important international peer reviewed journals in the field of plasma physics and fusion: *Nuclear Fusion, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, Journal of Fusion Energy*.

f) Lay the foundations for future fusion power plants by developing materials, technologies and conceptual design;

Indicator: Percentage of the Fusion Roadmap's milestones established for a period 2014-2018 reached by the Euratom Programme;

Current: new indicator, 0%

Target: 90%, including Report on Fusion Power Plant Conceptual design activities (2018);

Description of the indicator: new indicator which will be based on the roadmap for the fusion programme to be developed before 2014.

g) Boost Europe's industrial leadership in fusion technologies through development of the technology transfer process

Indicator: Number of spin-offs from the fusion research under Euratom Programme

Current: 33% of contracts resulted in spinoffs (2011); Target: 50% (2018)

Description of the indicator: new products or services developed by companies involved in the fusion research.

Indicator: Patents applications generated by European fusion laboratories

Current: 2-3 new patents per year (2011); Target: on average 4-5 new patents per year (2018);

h) Ensure availability of research infrastructures for nuclear research;

Indicator: Number of researchers using fusion research infrastructures through mobility support

Current: ca. 800 (2008), Target: 1200 (2018);

Description of the indicator: mobility scheme under fusion programme supports short term visits of European scientists to the fusion facilities such as JET.

6.2. Indicators for direct actions

a) Improve nuclear safety including, fuel and reactor safety, waste management and decommissioning; and emergency preparedness

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support nuclear fuel and reactor safety, waste management, decommissioning and emergency preparedness)

Current: 45 (2010); Target: 50 (2018)

b) Improve nuclear security including: nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics)

Current: 15 (2010); Target: 20 (2018)

c) Raising excellence in nuclear science base for standardisation

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support EU standardisation.

Current: 30 (2010); Target: 30 (2018)

d) Foster knowledge management, education and training

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and training programmes)

Current: 20 (2010); Target: 18(2018)

e) Support to EU policy and evolving legislation on nuclear safety and security

Indicator: Policy support impact (Number of JRC reports used as reference for EU legislation)

Current: 0 (2010); Target: 2 (2018)

Indicator: Policy support productivity (Number of major JRC annual work plan deliverables with tangible impact at the level of nuclear policy makers: reports and training programmes)

Current: 40 (2010); Target: 45(2018)

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[i] Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, UK

[ii] Prospects for fusion, C. H. Llewellyn Smith, *Nuclear Physics* 751 (2005) 442c–452c; See also The Sustainable Nuclear Energy Technology Platform – A vision Report http://www.snetp.eu/

[31bis] Final Report of the European Fusion Power Plant Conceptual Study (PPCS), EFDA 2005

[iii] http://www.iaea.org/newscenter/focus/fukushima/

[iv] http://ec.europa.eu/energy/nuclear/safety/stress_tests_en.htm

[v] Strategic Research Agenda of the Sustainable Nuclear Energy Technology Platform, SNETP 2010

[vi] Proposal for a Council Directive on the management of spent fuel and radioactive waste, COM(2010)618, 3 November 2010

[vii] Special Eurobarometer 297: *Attitudes towards radioactive waste*, published in June 2008.

[viii] See for example: http://ec.europa.eu/research/energy/pdf/euradwaste_08_en.pdf and 'Radioactive waste in perspective', NEA2010

[ix] Vision Report of the Implementing Geological Disposal of Radioactive Waste Technology Platform, 2010 http://www.igdtp.eu/

[x] Nuclear education and training: cause for concern? OECD NEA 2000

[xi] The need for nuclear education culture have been underlined by the Council of the European Union – see conclusions on the need for skills in the nuclear field, 2891st Competitiveness (Internal Market, Industry and Research) Council meeting, Brussels, 1 and 2 December 2008

[xii] Uranium 2009: Resources, Production and Demand ('Red Book'); OECD, IAEA, August 2010

[xiii] Assessment of Nuclear Energy Systems Based on a Closed Nuclear Fuel Cycle with Fast Reactors, IAEA, 2010

[xiv] Generation-IV International Forum 2009 Annual Report (published by the OECD Nuclear Energy Agency) http://www.gen-4.org/PDFs/GIF-2009-Annual-Report.pdf

[xv] Report of the High Level and Expert Group on European Low Dose Risk Research, Jan. 2009 (http://www.hleg.de/fr.pdf)

[xvi] R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan, JRC 2007

[xvii] http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm

[xviii] AREVA, EdF, Vatenfall, Iberdola, EnBW Energie Baden-Wurttemberg, Fortum, CEZ, URENCO

[xix] Some corporate reports indicate that corporate research priorities cover to some extent the challenges indicated in section 1, in particular: lifetime plant management, improvement of fuel utilisation, development of new LWR reactors (generation III) and waste management. Some companies have also indicated investments in the front and back end of the nuclear fuel cycle. Prepared on the basis of the latest version of annual reports from the following companies: AREVA, EdF, Vatenfall, Fortum

[xx] Sixth Situation Report on Radioactive Waste and Spent Fuel Management in the European Union, COM(2008)542 final and SEC(2008)2416

[xxi] http://www.gen-4.org/

[xxii] The scientific success of JET, M. Keilhacker *et al* 2001 *Nucear Fusion* 41 1925

[xxiii] Article 24 of the Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project, Official Journal of the European Union, L 352762, 16 December 2006

[xxiv] Commission's survey (2009) of companies involved in upgrade and construction projects in fusion

[xxv] Data from http://wds.iea.org

[xxvi] This estimate is based on IEA data available for some Member States only (Austria (2000-2008), Belgium (2007 only), Czech Republic (2003-2007), Denmark (2000-2007), Finland (2000-2008), France (2000-2008), Germany (2000-2009), Hungary (2000-2009), Italy (2000-2007), Netherlands (2000-2003, 2005-6), Slovak Republic (2002-2004, 2008-9), Spain (2000-2006), Sweden (2003-2009),

[xxvii] R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan, JRC 2009

xxviii For more details see http://ec.europa.eu/research/energy/euratom/fusion/eu-fusion/index_en.htm, also http://www.efda.org/

xxix Source: European Commission

xxx http://eur-lex.europa.eu/en/treaties/index.htm

xxxi This is the focus of the NULIFE project (nulife.vtt.fi) and related projects– the NULIFE, when created, will be able to provide a service for industry which will ensure common standards.

xxxii See for example conclusions of the Interim Evaluation of Euratom 7th Framework Programme http://ec.europa.eu/research/evaluations/index_en.cfm?pg=fp7-evidence

xxxiii information available on http://www.irsn.fr/

xxxiv Journals analysed in Scopus database (www.scopus.com): Nuclear Fusion, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, Journal of Fusion Energy.

xxxv Calculated on the basis of data from Eurostat

xxxvi For details see http://ec.europa.eu/research/energy/pdf/200905_fusion_industry.pdf

xxxvii Estimating Spillover Benefits and Social Rate of Return of Fusion Research, Development, Demonstration and Deployment Program, EFDA Socio-Economic Research on Fusion, Edgard GNANSOUNOU, Denis BEDNYAGIN, EPFL, Switzerland, 2007

xxxviii For details see http://ec.europa.eu/research/energy/pdf/spin_off_en.pdf