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**COMMISSION STAFF WORKING DOCUMENT**

**INTERIM EVALUATION OF INDIRECT ACTIONS OF THE EURATOM  
RESEARCH AND TRAINING PROGRAMME**

*Accompanying the document*

**REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE  
COUNCIL AND THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE**

**Interim evaluation of the Euratom Research and Training Programme 2014-2018**

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## 1. EXECUTIVE SUMMARY

This Commission staff working document (SWD) presents the interim evaluation of indirect actions funded through the Euratom research and training programme 2014-2018 (the 'Euratom programme', or the 'programme'). A separate SWD presents the interim evaluation of direct actions. These two documents accompany the Commission report which sets out the Commission's observations and the findings and recommendations from independent expert groups assisting the Commission in carrying out this evaluation.

In accordance with Council Regulation 1314/2013, the general objective of the Euratom programme is to pursue nuclear research and training activities with an emphasis on continuously improving nuclear safety, security and radiation protection. The programme's scope and objectives are based on the compromise reached by the Council following the Fukushima nuclear accident. As a result, the Euratom programme contains objectives allowing coordination of nuclear research in some specific areas. The compromise is also reflected in the budget allocated for the fission part of the programme. The Commission notes that for the moment a high level of expertise in nuclear research is still available in Europe, and one of the aims of a European research and training programme is to maintain this potential for the future.

The interim evaluation finds that the programme's original rationale for intervention and its objectives are highly **relevant**. As confirmed by the Commission Expert Group, Euratom research focuses on challenges of importance to the public. The programme provides a balance between the need to support the safety of nuclear technology in Europe and the need to underpin safety in the future. Euratom waste management projects help to better understand the issues relevant to the effective management of radioactive waste in the EU. These are issues, such as the safety of future geological disposal facilities, the conditioning of radioactive waste, the long-term behaviour of spent fuel in a repository and the clean-up of decommissioned sites. Euratom research on radiation protection will lead to an improved knowledge of the effects of low doses of ionising radiation on the human biota. This will translate into a more effective and safer use of radiation and radionuclides in medical diagnostic and therapeutic practices. Public consultation revealed that the programme is also important for research stakeholders and end-users of nuclear research – the nuclear industry, operators of power plants and safety authorities. The programme's relevance is also shown by the sustained interest in the competitive calls issued under the fission part of the programme.

On effectiveness, after three years of implementation of the Euratom programme (2014-2016), evidence indicates that progress is being made in delivering on all Euratom objectives in indirect actions, as set by the Council Regulation. In fusion there is significant progress on the agreed roadmap toward demonstrating the feasibility of fusion as a future energy source (47% of the research milestones for 2014-2018 were achieved by 2016). In particular, the programme is delivering key information and data of relevance for the future operation of ITER, the ground-breaking global research facility under construction in France. By confirming appropriate ITER design options and/or investigating relevant plasma scenarios and optimising plasma operation and control measures, Euratom research reduces costs and associated ITER construction and operation risks. The EUROfusion consortium coordinated the joint exploitation of three research tokamaks and supporting facilities, and Euratom supported access to these infrastructures for more than 1000 researchers in 2016. As a result, European researchers submitted about 1000 articles in high-impact peer-reviewed scientific journals.

First reports show progress by fission projects in the three key areas of research (safety, waste management and radiation protection) with half of them having a safety focus. While the number of publications is understandably low at what is only the start of project implementation, Euratom projects have already set up substantial teams of researchers (almost 1200 people) and are reporting progress in reaching milestones.

Euratom is also at the forefront in implementing the new instruments in the area of **joint programming of research**. In 2014, the Euratom programme successfully pioneered the first use of the European Joint Programme (EJP) co-fund action with the major EUROfusion grant agreement for fusion energy research. Since then, in 2015, Euratom introduced another Joint Programme co-fund action (CONCERT) for radiation protection focused on achieving breakthroughs in understanding the effects of low doses of ionising radiation.

The results of the interim evaluation show a good overall level of **efficiency** in programme management (in particular, grant management and proposal evaluation in the case of indirect actions) and implementation by the Commission. The Commission is keeping its own administrative expenditure for indirect actions below the target of an average of 7% of the operational budget for 2014-2018, and available data shows that the planned target of 6% for 2018 will be met. Simplification measures introduced since the start of the programme have greatly improved efficiency, notably for the time-to-grant (TTG). The average TTG for the Euratom 7th Framework Programme was 315 days, whereas it was 261 days for the 23 projects launched following the 2014-2015 call, and decreased further to only 229 days for the 25 projects from the 2016-17 call.

A key part of the **European added value** of Euratom indirect actions, as underlined by stakeholders, is the EU's ability to mobilise a wider pool of excellence, expertise and multi-disciplinarity in nuclear research than individual Member States could. Through cooperative research and innovation, the Euratom programme also enables a Europe-wide approach to the improvement of nuclear safety and radiation protection in all areas of application. This complements the Euratom Directives on nuclear safety, radioactive waste management and basic safety standards and involves demonstrable scientific and technological progress in all areas that would not have been possible without a collaborative pan-European approach. The Euratom programme also enables a much more broad-based coordination throughout Europe of education and training, the use of research infrastructures and international cooperation. This is of particular benefit to smaller Member States, which can then take advantage of economies of scale afforded by the Europe-wide pooling effect.

## 2. ACRONYMS AND GLOSSARY

Type	Name or abbreviation	Description
Nuclear	ALLIANCE	Research Platform to coordinate and promote European research on Radioecology ( <a href="http://www.er-alliance.org/">http://www.er-alliance.org/</a> )
	EFDA	European Fusion Development Agreement
	ENEN	European Nuclear Education Network
	ESNII	European Sustainable Nuclear Industrial Initiative
	EUROfusion	European Consortium implementing a comprehensive joint programme in line with the fusion roadmap
	Generation- II/-III	Current generations of nuclear power plants
	Generation- IV	Generation IV (advanced fission nuclear systems)
	HLW	High-Level (radioactive) Waste
	MELODI	Multidisciplinary European Low-Dose Initiative ( <a href="http://www.melodi-online.eu/">http://www.melodi-online.eu/</a> )
Implementation and monitoring	Applicant	Legal entity submitting an application for a call for proposals.
	Application	The act of involvement of a legal entity in a Proposal. A single Applicant can apply in different proposals.
	High Quality Proposal	A proposal that scores above set evaluation threshold, making it eligible for funding.
	KPI	Key Performance Indicators in the legal basis of Euratom Programme
	Newcomer	A participant in Euratom Programme who was not involved in Euratom FP7 Project
	Participant	Any legal entity carrying out an action or part of an action under Euratom Programme 2014-2018.
	Participation	The act of involvement of a legal entity in a Project. A single Participant can be involved in multiple Projects.
	Project	Successful proposals for which a Grant Agreement is "signed".
	SME	Small or Medium-Sized Enterprise.
	Success rate	The number of proposals that are retained for funding over the number of eligible proposals.
	Time to grant	The elapsed time between the call closing date and the signing of the grant agreement, which marks the official start of the project.
	TRL	Technology Readiness Levels are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain: TRL 1 – basic principles observed; TRL 2 – technology concept formulate; TRL 3 – experimental proof of concept; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment; TRL 6 – technology demonstrated in relevant environment; TRL 7 – system prototype demonstration in operational environment; TRL 8 – system complete and qualified; TRL 9 – actual system proven in operational environment
Types of action	CSA	Coordination and Support Action
	IA	Innovation Action
	EJP-COFUND	European Joint Programme Cofund Action
	RIA	Research and Innovation Action
Country group	Third Country	A state that is not a Member State of the EU. "Third Countries" do not include Associated Countries.
	Associated Country	Third Countries that are party to an association agreement with the Euratom Research and Training Programme. They participate in Euratom Programme under the same conditions as EU Member States. 2 countries are associated to Euratom Programme: Switzerland (since 1979) and Ukraine (since 2016)
	EU13	BG - Bulgaria, LT - Lithuania, SK - Slovakia, CY - Cyprus, LV - Latvia, CZ - Czech Republic, MT - Malta, EE - Estonia, PL - Poland, HR - Croatia, RO - Romania, HU - Hungary and SI – Slovenia
	EU15	AT- Austria, BE - Belgium, DE - Germany, DK - Denmark, EL - Greece, ES - Spain, FI- Finland, FR - France, IE - Ireland, IT - Italy, LU - Luxembourg, NL - Netherlands, PT - Portugal, SE - Sweden and UK - United Kingdom
	NMS	EU New Member States (since 2004)
Other	DG RTD	European Commission's Directorate-General for Research and Innovation
	DG JRC	European Commission's Joint Research Centre
	EESC	European Economic and Social Committee
	ESIF	European Structural Investment Funds
	EFSI	European Fund for Strategic Investments
	EAV	European Added Value

### **3. INTRODUCTION**

#### **3.1. Purpose of the evaluation**

This Commission Staff Working Document provides support and evidence for the Commission report on the interim evaluation of the Euratom Research and Training Programme 2014-2018, in line with Article 22 of Regulation 1314/2013<sup>1</sup> and Commission's Better Regulation Guidelines<sup>2</sup>. The evaluation aims at improving the implementation of the Euratom programme by already drawing some lessons for the Work Programme for the year 2018, and by informing the design of the proposal for the extension of the Programme for 2019-2020 and future Euratom Programmes. It assesses progress made towards achieving the objectives of the Euratom Programme, the efficiency and use of resources, its continued relevance, the coherence within the Programme and with other instruments, and its EU added-value.

#### **3.2. Scope of the evaluation**

This interim evaluation covers the implementation of indirect actions during approximately the first half of the current Euratom Programme (2014 to 2016). The direct actions implemented by the Joint Research Centre have been evaluated separately and are covered in a separate Staff Working Document. Furthermore, it reports on the wider impacts of previous Euratom Programmes.

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<sup>1</sup> OJ L 347, 20 December 2013

<sup>2</sup> More information here: [http://ec.europa.eu/smart-regulation/guidelines/toc\\_guide\\_en.htm](http://ec.europa.eu/smart-regulation/guidelines/toc_guide_en.htm)

## 4. BACKGROUND TO THE INITIATIVE

### 4.1. Description of the initiative and its objectives

In accordance with the Euratom Treaty, nuclear research is a competence shared between Euratom and Member States<sup>3</sup>. The Euratom Programme is the EU's main instruments for the funding of nuclear research in Europe, with a budget of EUR 1.6 billion for the period 2014-2018.<sup>4</sup>

The objectives of the Euratom Programme are established by Article 3 of the Council Regulation (Euratom) No. 1314/2013:

*1. The general objective of the Euratom Programme is to pursue nuclear research and training activities with an emphasis on continuous improvement of nuclear safety, security and radiation protection, notably to potentially contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way. The general objective shall be implemented [...] in the form of direct and indirect actions which pursue the specific objectives set out in paragraphs 2 and 3 of this Article.*

*2. The Euratom Programme indirect actions shall have the following specific objectives:*

- (a) supporting safety of nuclear systems;*
- (b) contributing to the development of safe, longer term solutions for the management of ultimate nuclear waste, including final geological disposal as well as partitioning and transmutation;*
- (c) supporting the development and sustainability of nuclear expertise and excellence in the Union;*
- (d) supporting radiation protection and development of medical applications of radiation, including, inter alia, the secure and safe supply and use of radioisotopes;*
- (e) moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities;*
- (f) laying the foundations for future fusion power plants by developing materials, technologies and conceptual design;*
- (g) promoting innovation and industrial competitiveness;*
- (h) ensuring availability and use of research infrastructures of pan-European relevance.*

For the purpose of the interim evaluation, the intervention logic of the Euratom Programme has been reconstructed based on the programming documentation (see Figure 1). It describes the links between the problems to be tackled, the objectives to be achieved, the activities and the expected impacts<sup>5</sup>. It distinguishes between outputs (the direct products from the actions,

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<sup>3</sup> Article 4 of Euratom Treaty

<sup>4</sup> Article 4 of the Council Regulation (Euratom) 1314/2013

<sup>5</sup> The intervention logic is based on the following documents: Euratom Programme's Impact Assessment that establishes and assesses the problem definition, objectives and options of the programme; The Euratom Programme's Regulation that defines the general and specific objectives, priorities, budget and principles for



such as reports, trained researchers, prototypes, new infrastructures), results (that relate to benefits for direct beneficiaries from their participation) and impacts (the wider long-term effects of the Euratom Programme).

Where possible, the previous Euratom Framework Programme (FP7, 2007-2013) and the related ex-post evaluation have been used as a baseline for this interim evaluation. An overview of the results and impacts generated through Euratom FP7 is provided in Section 7.3.

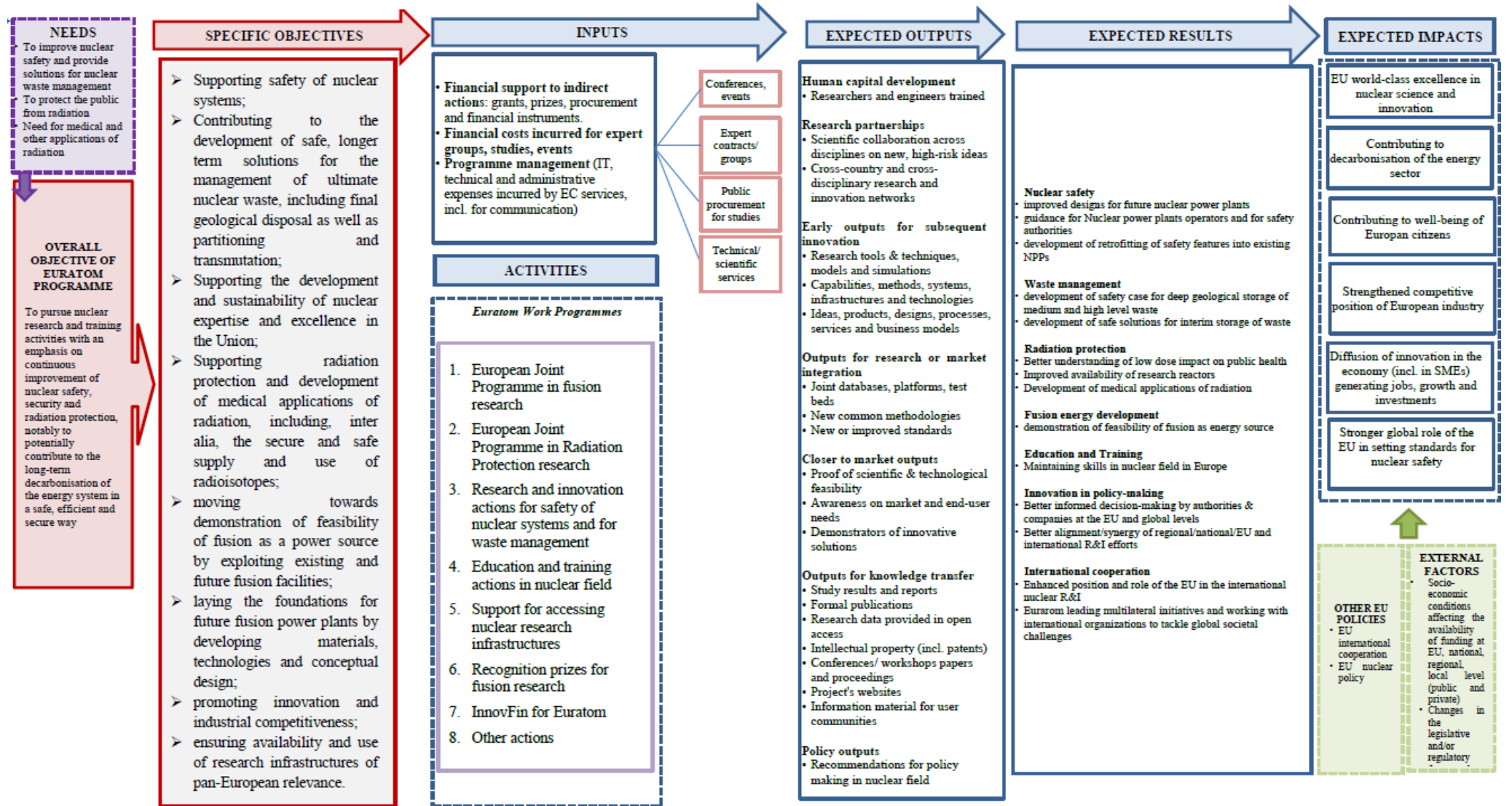
In fusion research this evaluation considers the transition from the FP7 instruments such as the many bi-lateral contracts between Euratom and Member States' laboratories, and the multilateral instrument under the European Fusion Development Agreement. In passing from Euratom FP7 to the current Euratom Programme, the approach to fusion research has undergone a major transition with the creation of EUROfusion. Research activities are now managed within this consortium.

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the management of the programme; The Work Programmes 2014-2015 and 2016-2017, which detail the activities undertaken so far.

Figure 1: Intervention logic of the Euratom Programme

# INTERVENTION LOGIC OF EURATOM PROGRAMME 2014-2018



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## 4.2. Evaluation questions

This interim evaluation is structured around five evaluation criteria of relevance, efficiency, effectiveness, coherence and EU added value<sup>6</sup>.

## 4.3. Method

In line with the Council Regulation, the interim evaluation was carried out by the Commission with the assistance of the Commission group of independent experts (CEG). The interim evaluation started in June 2016. Work of the expert group has been guided by Terms of Reference adopted by the Commission<sup>7</sup>. The exercise has been based on the following data sources:<sup>8</sup>

- Commission's statistics concerning the implementation and results of Euratom calls for proposals (2014/15, and 2016/17)<sup>9</sup>;
- 2014-2016 periodic reports from EUROfusion and fission projects<sup>10</sup>
- Report from the Commission Expert Group for interim evaluation of indirect actions of Euratom Programme 2014-2018;
- Study by E&Y consultancy on governance and management of EUROfusion, and on fission research.

The feedback from an on-line public stakeholder consultation carried out in the context of this interim evaluation has also been used. More than 320 stakeholders replied and 10 stakeholder position papers were submitted.<sup>11</sup>

The main limitation of this interim evaluation concerns its timing: it is taking place only three years after the beginning of the Euratom Programme, whereas most projects (i.e. fission projects following open calls for proposals) have only just started and it is too early to present a complete picture of results and impacts. Though some results may be expected within such a period of time, it would require more time for more significant impacts to emerge, such as influence on the regulatory framework, or development of new materials and/or techniques.

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<sup>6</sup> Relevance: assessment of whether the original objectives of Euratom Programme are still relevant and how well they still match the current needs and problems. Effectiveness: how successful Euratom Programme has been in achieving or progressing towards its objectives. Efficiency: the relationship between the resources used by Euratom Programme and the changes it is generating. Coherence: how well or not the different actions work together, internally and with other EU interventions/policies. EU added value: assessment of the value resulting from Euratom Programme that is additional to the value that could result from interventions which would be carried out at regional or national levels.

<sup>7</sup> Commission decision (C(2016)3922) of 29.6.2016 setting up the Commission expert group on the interim evaluation of indirect actions of the Euratom Research and Training Programme (2014-2018)

<sup>8</sup> Further details on the methodologies adopted for this interim evaluation are provided in Annex 1.

<sup>9</sup> Euratom statistics are published in the Horizon 2020 Annual Monitoring reports - [https://ec.europa.eu/research/evaluations/index\\_en.cfm?pg=monitoring](https://ec.europa.eu/research/evaluations/index_en.cfm?pg=monitoring)

<sup>10</sup> Data on Euratom projects can be found on CORDIS website [http://cordis.europa.eu/projects/home\\_en.html](http://cordis.europa.eu/projects/home_en.html)

<sup>11</sup> A full analysis of the stakeholder consultation (both the questionnaire and the position papers) is provided in Annex 2. The SWD summarises key stakeholder input on relevant topics.

Some 'lower risk' actions have incremental and short-term effects, which are easier to capture and to report on, though 'high risk' actions (such as fundamental research) would result in more profound impacts only in the longer term (e.g. 10-20 years, and even beyond). These latter effects are also more difficult to capture through usual indicator systems, and often need complex investigative work to match outputs from projects carried out in the past with eventual impacts many years later, sometimes in different technical areas.

Data limitations include issues related to data availability and measurability of outcomes (e.g. most Euratom Key Performance Indicators (KPI) focus on outputs from research projects such as publications and patents), aggregation (e.g. difficulty in aggregating data covering the whole spectrum of programme coming from various data sources) and reliability of certain data (e.g. data on patents and publications are based on self-reporting by project coordinators).

Another limitation is the lack of benchmarks to compare performance. Worldwide there is no nuclear research programme similar to the Euratom Programme in terms of thematic coverage and depth. To overcome and mitigate these limitations, the SWD is transparent in indicating its data sources and all underlying sources are available.

## 5. IMPLEMENTATION STATE OF PLAY

### 5.1. Overview of programme inputs and activities

The Commission is responsible for research policy in the nuclear field in line with provisions of the Euratom Treaty. While the Council Regulation establishing the Euratom Programme 2014-2018 sets out the broad lines of action and the budget envelope, the Euratom Work Programmes define the priorities, usually on a biennial basis, as well as all details of the corresponding open calls for proposals in the 'fission' part of the programme. Following the opinion of the Programme Committee, consisting of Member States' representatives, Euratom Work Programmes are formally adopted by the Commission. Reacting to the calls for proposals, applicants from industry, academia, national nuclear research centres and other players submit proposals that are then evaluated by panels of independent experts. The Euratom Research and Training programme 'indirect actions', including any related calls for proposals, are managed by Directorate-G ('Energy') of DG Research & Innovation (DG-RTD).

Table 1 provides an illustration of the different types of actions used. The bulk of the budget is granted to European Joint Programmes, collaborative Research & Innovation projects (most specifically through Research and Innovation Actions) and the coordination and networking of research and innovation projects, programmes and policies (CSA). Other types of actions include recognition prizes and financial instruments (Innovfin). Coordination, support and other actions are used for studies, expert groups, conferences, as well as measures to promote the dissemination and exploitation of results.

Table 1. Types of funding actions in the Euratom Programme			
<b>Grants</b> (direct financial contribution in order to finance actions)	<b>Research and Innovation Action (RIA)</b>	Funding for research projects tackling clearly defined challenges, which can lead to the development of new knowledge or a new technology. Aimed at consortia of partners from different countries, industry and academia.	
	<b>Innovation Actions (IA)</b>	Funding is more focused on closer-to-the-market activities. For example, prototyping, testing, demonstrating, piloting, scaling-up etc. if they aim at producing new or improved products or services. Aimed at consortia of partners from different countries, industry and academia.	New instrument in Horizon 2020 and Euratom Programme 2014-2018
	<b>Coordination and support actions (CSA)</b>	Funding covers the coordination and networking of research and innovation projects, programmes and policies. Funding for research and innovation per se is covered elsewhere. Aimed at single entities or consortia of partners from different countries, industry and academia.	

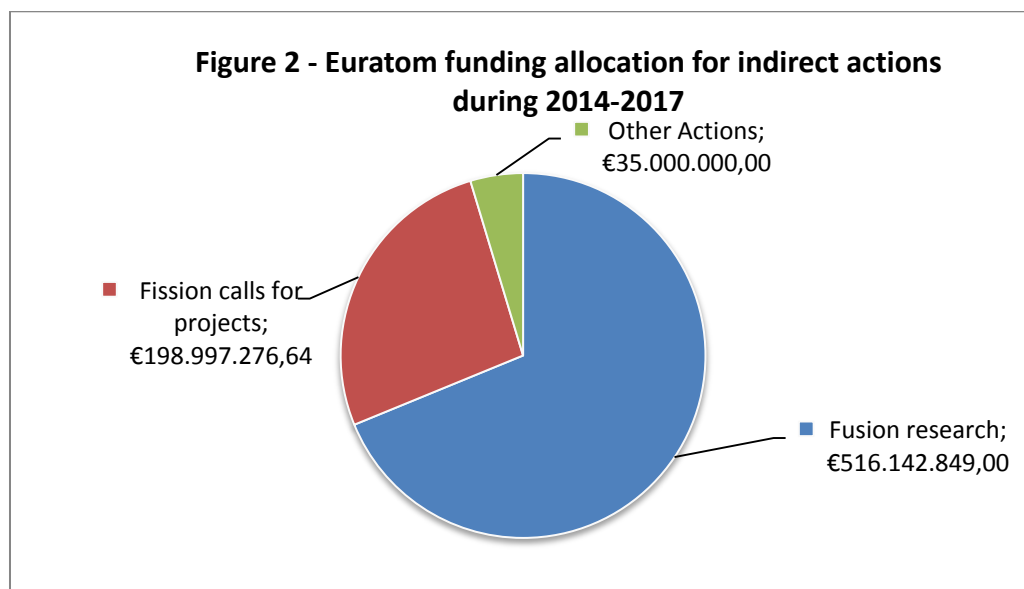
<b>Co-fund grants</b>	<b>European Joint Programme (EJP)</b>	Support Member States' research programmes in implementing a joint coordinated programme of activities. Aimed at entities owning/managing national research programmes. The EJP aims at attracting and pooling a critical mass of national resources in line with the Euratom Programme's objectives, and at achieving significant economies of scale.	New instrument in Horizon 2020 and Euratom Programme 2014-2018
<b>Loan-based financial instruments</b>	<b>InnovFin</b>	Loans to support fission research and innovation projects concerning the construction or refurbishing of research infrastructures	New instrument in Horizon 2020 and Euratom Programme 2014-2018
<b>Prizes</b>	<b>Recognition Prizes</b>	Financial prize following a contest in order to give recognition of past achievements and induce future activities.	New instrument in Horizon 2020 and Euratom Programme 2014-2018

Source: European Commission

## 5.2. Overview of implementation status after three years

### 5.2.1. Overview of funding allocation during 2014-2017

On the basis of two biennial work programmes (2014-15 and 2016-17) a total amount of EUR 750 million was allocated to indirect actions of the Euratom programme. As figure 2 shows, 69% of this budget was assigned to fusion research, while 31% was assigned to fission research, including calls for proposals and other actions such as public procurement and financial instruments. Table 2 provides more details on the budget allocation, with breakdown per biennial work programme.



Source: European Commission

The 2014-2015 work programme provided payment in annual instalments for the grant for EUROfusion consortium and for operating contract for the JET fusion research facility. On the basis of both work programmes the Commission launched biennial calls for proposals.

<b>Table 2. Budget allocation under Euratom Research and Training Programme 2014-2018</b>		
<b>Period</b>	<b>Research field</b>	<b>Expenditure</b>
2014-2015	Fusion research	€ 231,880,687
	Fission calls for projects	€ 90,144,332.11
	Other actions (Supporting access to Jules Horowitz Research reactor)	€ 15,000,000
	<b>Total</b>	<b>€ 337,025,019</b>
2016-2017	Fusion research	€ 284,262,162
	Fission call for projects	€ 108,852,944.64
	Other actions (InnovFin)	€ 20,000,000
	<b>Total</b>	<b>€ 413,115,106.75</b>
<b>Total for 2014-2017</b>		<b>€ 750,140,125.75</b>

*Source: European Commission*

### *5.2.2. Results of three calls for proposals in the fission research*

The 1<sup>st</sup> open call in the Euratom fission programme resulted in 62 eligible proposals. The cumulative amount of Euratom contribution requested in these proposals was EUR 228.08 million, which represented 2.5 times the available budget foreseen in the Euratom Work Programme 2014-2015. After evaluation, 55 proposals scored above threshold while 21 proposals were initially retained for funding. Later, a further proposal was funded from the reserve list. In addition, a second, supplementary call was opened concerning research for security of supply of nuclear fuel, 4 proposals were found eligible and the Euratom contribution requested in these proposals was EUR 5.93 million. As a result of these two calls, 23 proposals were funded with a total Euratom financial contribution of EUR 90.14 million.

The average Euratom funding per signed grant was almost EUR 4 million. The success rates for Euratom indirect actions were 35% in terms of eligible proposals and 38.5 % in terms of Euratom funding requested, which compare with Horizon 2020 averages of 13.39% and 14.51% respectively. The significantly higher Euratom success rates are due to the high degree of consolidation of the research efforts in this domain, and were apparent also in previous framework programmes.

It is important to note that the Euratom Programme does not include some of the sub-programmes available under EU Horizon 2020, such as those specifically supporting SMEs.

Grant Agreements for 23 projects were signed in the course of 2015. The average duration of each project is 47 months.

A total of EUR 15 million of fission funding was not allocated to the above call, instead being allocated to supporting future access of Euratom researchers to the Jules Horowitz Reactor (JHR), currently in the final stage of construction at CEA Cadarache.



Following the call for proposals under WP2016/17, 70 eligible proposals were received by 5 October 2016 and all 25 selected proposals were signed by 5 June 2017. The cumulative amount of Euratom contribution requested in these 70 proposals was EUR 266.76 million, which represented 2.5 times the available budget foreseen in the Euratom Work Programme 2016-2017. At the evaluation stage, 59 proposals scored above threshold and 25 proposals were retained for funding for a total Euratom financial contribution of EUR 108.85 million.

On average, the amount of Euratom funding allocated per signed grant was almost EUR 4.3 million. The success rates for Euratom indirect actions were 36% in terms of eligible proposals and 41% in terms of Euratom funding requested.

Participation trends in proposals show that labs from new Member States are well integrated into the European nuclear research (EU-13/EU-28 participation rate is relatively high at 17.93% compared to the Horizon 2020 average of 9.87%). Participation from associated (Switzerland and Ukraine) and third countries is 5.83% and 3.98% respectively, while participation from the private sector and SMEs is 23.47% and 6.38% respectively. The average project duration is 46.4 months.

The 2016/17 call included two topics of cross-cutting research of importance to both the fission and fusion research communities, to be funded equally from the fission and fusion budget lines, and one project from each of these topics is included in the above 25 selected proposals. In addition, the WP2016/17 also made available for the first time the InnovFin loan-based financial instrument, managed by EIB and the European Commission, to support research infrastructure projects in fission and radiation protection. EUR 20 million were earmarked for loan guarantees using this instrument.

### *5.2.3. Fusion energy research actions*

In fusion energy research, a new framework was established in 2014 that replaced previous instruments<sup>12</sup>. This new framework<sup>13</sup> consists of two principal actions. The first concerns multiannual support (EUR 425 million over the period 2014-2018) through a European Joint Programme (EJP) co-fund action Grant Agreement with the EUROfusion consortium of national fusion laboratories and institutes<sup>14</sup> to implement a comprehensive goal-oriented joint programme in line with the roadmap to fusion electricity<sup>15</sup>. The second is support, through a five-year ad hoc bilateral contract under Article 10 of the Euratom Treaty, for the continued operation of JET, the Joint European Torus<sup>16</sup> (EUR 283 million, 2014-2018), as the research device exploited under the EUROfusion joint programme. In line with article 4(5) of the Council Regulation (Euratom) No 1314/2013, the Euratom Work Programme 2014-2015 constitutes a five-year financing decision for both the European Joint Programme (Grant

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<sup>12</sup> The European Fusion Development Agreement (EFDA) and the Contracts of Association between the Commission and national fusion laboratories, which all expired at the end of 2013

<sup>13</sup> Established in accordance with point (i) of the Annex I of the Council regulation (Euratom) No 1314/2013.

<sup>14</sup> For more information see <https://www.euro-fusion.org/>

<sup>15</sup> 'Fusion Electricity – A roadmap to the realisation of fusion energy', <https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/>

<sup>16</sup> For more information see <https://www.euro-fusion.org/jet/>

Agreement with EUROfusion) and the 'New JET Operation Contract'. On this basis, the Commission pays every year instalments following approval of the annual reports and work plans submitted by the EUROfusion consortium and JET operator.

#### *5.2.4. Progress towards the Euratom programme's objectives*

The Council Regulation (Euratom) 1314/2013 establishing the Euratom programme provides a set of specific objectives to be funded by the Commission while detailed research actions are set at the level of Work Programmes. Furthermore, detailed milestones and targets are fixed at the level of grants which are monitored closely by the Commission. Progress of the programme can be also measured by a set of Key Performance Indicators provided for in the Annex II to the Council Regulation.

Table 3 and analysis carried out for this SWD (see Section 7 on the efficiency of the programme for more details) show that Euratom programme is on track to achieve its objectives in fission and fusion:

In the first three years of its establishment (2014-16), the EUROfusion consortium has made tangible and incremental progress along the fusion roadmap with the vast majority of the agreed deliverables and milestones achieved. This progress is further exemplified by an increasing number of peer-reviewed publications, PhDs students, physics and engineering grantees as well as the number of researchers having access to pan-European research infrastructures.

In fission and radiation protection, the Commission has launched a portfolio of 48 projects in all main fields of research as requested by the Council Regulation (including 2 cross-cutting fission-fusion projects). First periodic reports from launched projects show that while the number of reported publications is relatively low at the start of the project implementation, the Euratom fission projects already established substantial teams of researchers (almost 1200 people) and they report progress made in terms of milestones reached.

The Commission launched two European Joint Programme in both fields (EUROfusion and CONCERT) further integrating the research efforts of stakeholders in Member States. A third Joint Programme on research for nuclear waste management is in an advanced stage of preparation thanks to the JOPRAD project launched in 2015.

<b>Table 3 - Key performance indicators for indirect actions in fission and fusion research under Euratom Research and Training Programme 2014-2018</b>					
<b>Key performance indicator</b>	2014	2015	2016	2017	Total
The number of projects (joint research and/or coordinated actions) likely to lead to a demonstrable improvement in nuclear safety practice in Europe	8		9		17
The number of projects contributing to the development of safe long term solutions for the management of ultimate nuclear waste	5		5		10
The number of projects likely to have a demonstrable impact on regulatory practice regarding radiation protection and on development of medical applications of radiation	1		1		2 <sup>17</sup>
The number of researchers' and engineering grants in the Euratom fusion programme	17	28	31	n/a	76
The number of fission and fusion publications in peer-reviewed high impact journals <sup>18</sup>	200	450	325	n/a	975
The percentage of the Fusion Roadmap's milestones, established for the period 2014-2018, reached by the Euratom Programme	13%	31%	47%	n/a	-
The number of spin-offs from the fusion research under the Euratom Programme	1	2	0	n/a	3
The patents applications generated and patents awarded on the basis of research activities supported by the Euratom Programme <sup>19</sup>	1	2	1	1	5
The number of researchers having access to research infrastructures through Euratom Programme support <sup>20</sup>	872	958	1039	n/a	2869

Source: European Commission, EUROfusion annual reports and periodic reports from fission projects

<sup>17</sup> This number does not include projects launched within framework of CONCERT European Joint Programme in radiation protection research

<sup>18</sup> Based on data available from EUROfusion and from 22 fission projects

<sup>19</sup> For fission and fusion

<sup>20</sup> Data will be available at the end of the projects (for fission).

## 6. RELEVANCE OF THE EURATOM PROGRAMME

### 6.1. Is the Euratom Programme tackling the right issues?

The general objective of the Euratom programme in accordance with Council regulation 1314/2013 is to pursue nuclear research and training activities with an emphasis on continuous improvement of nuclear safety, security and radiation protection. **The scope and objectives of the programme are based on the compromise reached in Council following the Fukushima nuclear accident.** The compromise is also reflected in the budget for the fission part of the programme.

**The focus of the fission programme on safety-related issues addresses key societal concerns regarding the use of current nuclear technology, such as operational safety of nuclear power plants and safe disposal of the most hazardous forms of radioactive waste (high-level waste and spent nuclear fuel).** Nuclear safety and management of radioactive waste constitute major responsibilities at European level, with important Euratom Directives now in force, and the Euratom Programme complements this policy taking into consideration research agendas of technology platforms such as SNETP (Sustainable Nuclear Energy Technology Platform)<sup>21</sup> and IGDTP (Implementing Geological Disposal Technology Platform)<sup>22</sup> and of initiatives such as NUGENIA (Nuclear Generation II & III Association)<sup>23</sup> and radiation protection research platforms: MELODI (Multidisciplinary European Low-Dose Initiative)<sup>24</sup>, ALLIANCE (European Radioecology Alliance)<sup>25</sup>, NERIS (European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery)<sup>26</sup>, EURADOS (European Radiation Dosimetry Group)<sup>27</sup> and EURAMED (European Alliance for Medical Radiation Protection Research)<sup>28</sup>. Some of the projects supported by the Euratom Programme contribute, within the limits of the mandate given by the Council, to achieving the targets defined as part of the SET-Plan (Strategic Energy Technology Plan) process<sup>29</sup>.

**Outside the power sector, the Euratom Programme is addressing important societal concerns regarding the use of nuclear technologies in general, in particular the use of radiation in medical diagnostic and therapeutic practices.** Here, the focus is on the effects of low doses of radiation on the human biota. All exposure to ionising radiation carries a potential risk and related health detriment. In normal situations, doses and therefore risks are very low, with no clinically observable tissue effects and no epidemiological evidence of any detriment. Nonetheless, risks may not be zero, and late effects, including cancer in particular, remain possible. This calls for a multidisciplinary approach to radiation protection research,

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<sup>21</sup> <http://www.snetp.eu/>

<sup>22</sup> <http://www.igdtp.eu/>

<sup>23</sup> <http://www.nugenia.org/>

<sup>24</sup> <http://www.melodi-online.eu/>

<sup>25</sup> <http://www.er-alliance.eu/>

<sup>26</sup> <http://www.eu-neris.net/>

<sup>27</sup> <http://www.eurados.org/>

<sup>28</sup> <http://www.eibir.org/scientific-activities/joint-initiatives/european-alliance-for-medical-radiation-protection-research-euramed/>

<sup>29</sup> <https://setis.ec.europa.eu/implementing-integrated-set-plan/nuclear-safety-ongoing-work>

involving genomics, individual radio-sensitivity, and biological, biophysical and epidemiological aspects. This is the heart of the Euratom research programme's strategy in this field. The overall approach to radiation protection has been established over many decades by the International Commission on Radiological Protection (ICRP) and is based on the ALARA principle, i.e. radiation exposures should be 'As Low As Reasonably Achievable'. The need to protect health as well as the environment is also recognised in the Euratom Treaty, in which specific provisions are laid down in Chapter III on 'Health and Safety'. In particular, Article 31 of the Treaty calls for uniform Basic Safety Standards to be established within the EU. Annex I of the Treaty clearly mentions that research on health effects is within the scope of the Community (i.e. Euratom) research and training programme.

## **6.2. Relevance of Euratom programme in addressing European objectives**

The Euratom Programme plays an important role in supporting the implementation of Council Directive 2009/71/Euratom of 25 June 2009, and its revision 2014/87/Euratom, establishing a Community framework for the nuclear safety of nuclear installations, of Council Directive (2011/70/Euratom) of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, and of Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.

## **6.3. Is the Euratom Programme responding to stakeholder needs?**

In the case of the fusion programme, the approach adopted is to co-fund a comprehensive joint programme implemented by the EUROfusion consortium of all national fusion labs and institutes in Europe (30 partners in total: three in Germany, one in all other Member States except Luxembourg and Malta, one in Switzerland and, from 1 January 2017, one in Ukraine). In addition, there are also more than 100 linked third parties supported through the co-fund arrangement with EUROfusion. The joint programme is in line with the fusion roadmap to fusion electricity by around the middle of the century<sup>30</sup>, which was originally approved in late 2012 by all European labs as the long-term guiding strategy in the European fusion research effort. This comprehensive and goal-oriented roadmap, and associated joint programme, covers all aspects of the current effort needed to realise fusion energy in a realistic yet ambitious time horizon. It includes joint research, use of shared facilities, mobility of researchers, industrial involvement, education and training, international cooperation, etc. The present focus of the effort is support for the success of ITER, which is the one critical path on roadmap as a whole. To oversee the implementation of the joint programme, EUROfusion has set up a Programme Management Unit (PMU), established in Garching, Germany, and Culham, UK, with some 50 staff, most seconded from the beneficiaries. The head of the PMU, and the person with the key responsibility regarding the implementation of the joint programme, is the Programme Manager, who is appointed by and reports directly to the EUROfusion General Assembly, which is the principal decision-making body and made up of representatives of all the fusion labs involved (the grant beneficiaries).

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<sup>30</sup> <https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/>

EUROfusion, and therefore the Euratom programme, is responding to the needs of the European fusion community in this regard. The Euratom contribution to EUROfusion is, under the terms of the Grant Agreement with the Commission, up to 55% of the declared eligible costs of the consortium. In addition, under a bilateral contract with the Culham Centre for Fusion Energy (CCFE,UK – the JET operator) the Commission funds 87.5% of the cost of operation of JET, which is then offered to EUROfusion as an in kind contribution for exploitation by researchers across Europe.

Regarding the 'fission' programme, which is implemented largely by open calls for proposal, more than 80% of the respondents in the recent stakeholder consultation, carried out as part of the interim evaluation of the Euratom Programme 2014-2018, agreed that the frequency of the calls and their clarity were either 'good' or 'very good'. The majority of respondents (67%) also had a positive opinion on the transparency in the process of formulating the Euratom Work Programmes and on the ease of finding the right call topic for their proposal, even though 26% of respondents replied 'poor' or 'very poor' on these aspects.

#### **6.4. Programme attractiveness and take-up**

**The willingness of all national fusion labs to commit 'own resources' in the implementation of the EUROfusion joint programme indicates the attractiveness and their involvement in the Community joint effort.** In total, over the period 2014-2018, 45% of the consortium's budget will be committed from national programmes via EUROfusion beneficiaries to this joint effort. More precise figures will be known only at the end of the programme and following submission of all cost statements. At the start of the programme, and as part of the requirements for the awarding of a European Joint Programme (EJP) co-fund action Grant Agreement with the Commission, respective national fusion research programme 'owners' in Member States (usually at the level of ministries) signed a commitment to make national resources available for this action. Note that these resources are effectively in-kind (manpower, use of research infrastructures) and constitute about one half of the total resources of the joint programme, matched by the financial contribution from Euratom under the terms of the Grant Agreement.

In the 'fission' research, the demand for funds following the open calls is an indication of the value stakeholders attach to the programme. **Compared to Euratom FP7, the number of proposals submitted to the two fission calls so far in the Euratom Programme 2014-2018 has increased.** Whereas FP7 generated around 121 proposals during first three years, as of 1 January 2017 – after three years –139 proposals had been submitted under the Euratom programme 2014-2018.



#### **Public consultation: relevance of the Euratom Programme**

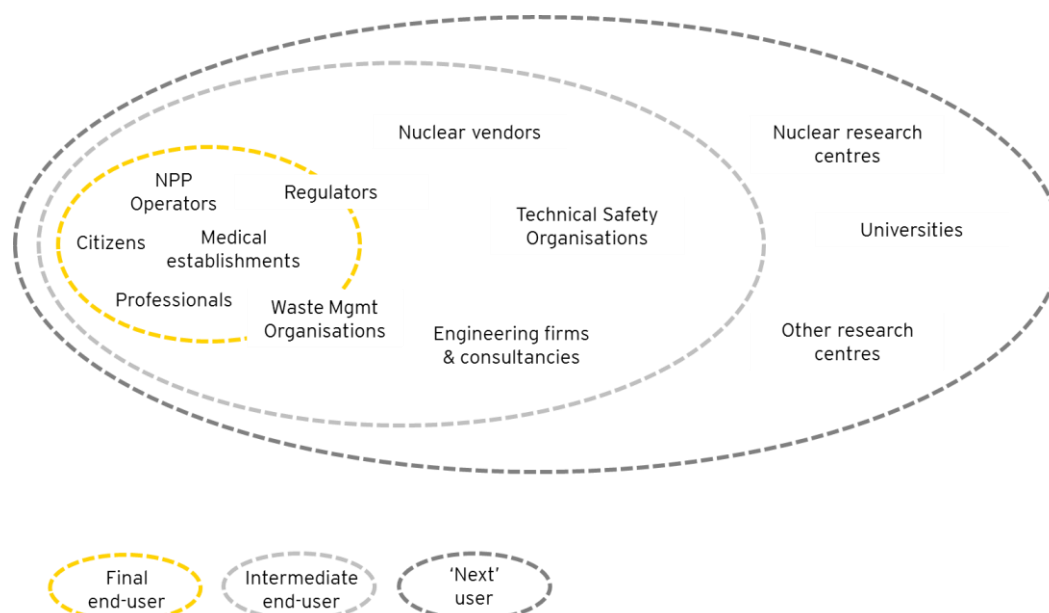
**The opinion of stakeholders regarding the current Euratom programme's relevance is positive: 80% of respondents agreed or strongly agreed that it is relevant.** This opinion varies from field to

field, showing the strongest support for E&T, waste and safety of existing reactors. The main reasons for participating in Euratom Programme are financial support, access to new knowledge and know-how, and unique collaboration opportunities with existing or new European or international partners. Interdisciplinary work and the opportunity to work with other types of actors also stand out.

## 6.5. End-users in the Euratom research and training programme

**Euratom programme attracts a substantial number of end-users of fission research. For 2014-2015, approximately 45% of participants were recognised end-users<sup>31</sup>.** For the purpose of the interim evaluation, three categories of end users have been identified<sup>32</sup> (see figure 3):

**Figure 3: Mapping of end-users in Euratom projects**



*Source: European Commission*

- **Next-users:** Rarely will a single Euratom project lead to breakthrough discoveries and the development of products or knowledge mature enough to pass on to the next echelon of user. In reality, the immediate end-users ('next' user) of the project results will be the same community of research centres and universities engaged in work on a given topic. Indeed, Euratom projects have demonstrated an ability to maintain coherence across time, with projects often building on the results of previous projects. These clusters of projects, over decades, produce increasingly mature knowledge that may eventually be transferred to intermediate or final end-users. The presence of final and intermediate end-users in

<sup>31</sup> E&Y study on fission research

<sup>32</sup> Ibidem

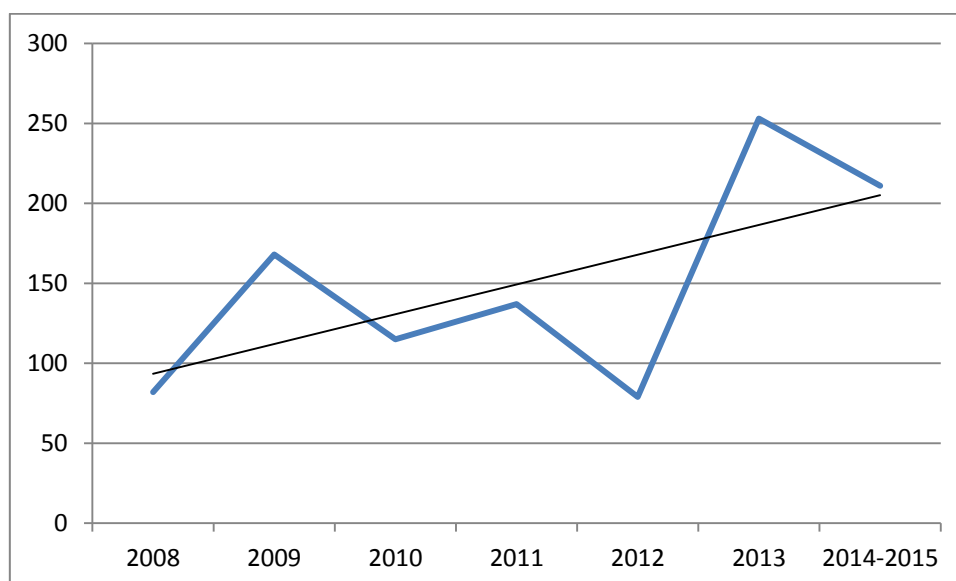
these projects is often peripheral and focused on providing strategic input to help ensure that the direction of research remains relevant to the ultimate needs of these actors.

- **Intermediate end-users:** This group of actors is a critical link in the chain between the research community and the final-end-users. As with the user of a mass consumer electronic, the final end-users in the nuclear sector do not have extensive technical knowledge of the products and knowledge (e.g. standards, procedures) they employ. They cannot build them from scratch, nor can they operate them without the support of a wide array of actors. These are intermediate end-users that are responsible for developing the underlying technology on an industrial scale, building the components of NPPs and other nuclear technologies (e.g. CT scanner), elaborating the regulatory frameworks for their use, and providing the final end-users with the technical support necessary to safely exploit nuclear technologies. The nuclear vendors that build reactors and other nuclear technologies, the regulators that set the ground rules for their use and the Technical Safety Organisations and other specialized firms that assist final end-users represent veritable end-users in themselves to a large extent.
- **Final end-user:** The final end-users are the actors that ultimately exploit nuclear technologies. In the field of reactor systems, this includes NPP operators and, to a certain extent regulators in their inspection and enforcement capacities. In terms of waste management, this includes waste management operators (public and private) and fuel manufacturers (P&T). Finally, in the field of radiation protection, this includes regulators, service providers (often regulators) and the medical community. End-users can be both organisations and individuals. The level of granularity can be an important consideration that will not be the same, for example, whilst developing a new reactor technology and developing a training module on nuclear safety. In a broader sense, it is important to also remember that society itself, which benefits from the safe operation of sustainable nuclear technologies, is always the final end-user.

Looking at the evolution of participation over time during Euratom FP7 and the first three years of the current Euratom programme, there is a slight upward trend (see figure 4). However, the number can vary considerably by year depending on the number and type of projects launched in a given year. For the 2014-18 programme, the picture appears to be largely the same as FP7, with approximately 45% of participants being either final or intermediate end-users during the period 2014-16.



**Figure 4: Evolution of the participation of final and intermediate end-users**



*Source: European Commission*

## 6.6. Geographical dimensions

**Analysis of participation of Member States that joined the EU in 2004 or later (hereinafter NMS) shows the substantial role played by research labs and universities from these countries, measured in terms of the number of project coordinators and budget received.** Regarding fission projects from the 2014/15 call, NMS accounted for 2 coordinators (PL, CZ), while in the 2016/17 call, NMS have 3 coordinators (BG, PL, LT). We observe also an increase of 6% in the total Euratom funding awarded to NMS, from the 2014/15 to the 2016/17 call (see table 4)

**Table 4 – Euratom financial contribution to new Member States in calls 2014-2016**

<b>Calls for proposals 2014/15</b>	
<b>EU-13</b>	<b>Euratom contribution in grants (€)</b>
CZ	3,702,753.25
SK	890,748.00
LT	692,477.33
PL	660,944.28
HU	615,853.00
BG	513,019.99
SI	462,367.42
EE	285,706.25
RO	175,312.00
LV	148,612.50
HR	66,937.50
<b>Total</b>	<b>8,214,731.52</b>

*Source: European Commission*

<b>Call for proposals 2016/17</b>	
<b>EU-13</b>	<b>Euratom contribution in grants (€)</b>
CZ	3,066,508.25
PL	1,671,231.25
HU	1,498,750.50
SI	1,147,326.25
LT	456,105.00
RO	330,952.33
SK	251,225.00
HR	183,976.00
LV	52,125.00
CY	23,625.00
<b>Total</b>	<b>€8,681,824.58</b>

## 7. EFFECTIVENESS OF THE EURATOM PROGRAMME

This section evaluates the progress being made towards the delivery of the objectives of the Euratom Programme. It also includes the evaluation of the main long-term impacts of the previous Euratom Framework Programme.

### 7.1. Effectiveness of Euratom supported fusion research

#### 7.1.1. *Implementation of fusion roadmap*

The Council Regulation provides three objectives concerning fusion research:

- Establishment of ‘European Fusion Programme – a grant (Programme co-fund action) is to be awarded to the legal entities established or designated by Member States and any third country associated to the Euratom Programme and that will develop a joint programme of activities implementing the roadmap towards the goal of electricity production by 2050’.
- ‘Moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities’
- ‘Laying the foundations for future fusion power plants by developing materials, technologies and conceptual design’

In order to implement these objectives, and following the expiry of Contracts of Association and European Fusion Development Agreement (EFDA), which had defined the structure of European fusion research for many years until 2013, the Commission put in place in 2014 a radically different approach based on a comprehensive European Joint Programme implemented by all national fusion labs in line with an agreed goal-oriented research roadmap to fusion electricity. The effective integration of all national efforts across Europe represents a first for any EU-promoted research field and includes comprehensive research activities in some 33 separate work packages (projects and taskforces), also covering education and training actions, international cooperation aspects, industrial involvement, centralised programme management, and the efficient use of key resources through a truly transnational access approach to key facilities. Programme and project management and related governance structures have become more transparent, with information readily available to the Commission services that retain overall monitoring and assessment responsibilities.

Euratom-funded research activities in fusion are centred around a fusion roadmap - *'Fusion Electricity – A roadmap to the realisation of fusion energy'*<sup>33</sup>. It is the guiding document of the Joint Programme, representing a comprehensive and detailed goal-oriented approach to the challenge of developing magnetic confinement fusion as an energy source. **Though fusion energy remains a long-term endeavour, the EUROfusion consortium has made tangible and incremental progress along this roadmap in the first three years (2014-16), with the vast majority of the agreed deliverables and milestones achieved, as set out in its annual**

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<sup>33</sup> See footnote 12

**Work Plans (Table 5), and this despite 2014 being a transitional year involving the setting up of the new organisational structure.**

<b>Table 5</b> <b>The percentage of the Fusion Roadmap's milestones established for the period 2014-2018 that have been achieved by EUROfusion</b>				
Milestones to be achieved by end of year indicate (forecast) <sup>34</sup>				
2014	2015	2016	2017	2018
13 %	31 %	54 %	75 %	90%
Actual results according to annual reporting				
13 %	31%	47%	n/a	n/a

Source: European Commission, annual reports from EUROfusion

The fusion Roadmap is articulated in eight Missions addressing key issues for developing fusion as an energy source. The Commission Expert Group concluded that following the definition of the Roadmap in 2012, the Euratom programme has made substantial progress to secure the success of ITER and lay the foundation for a demonstration fusion power plant (DEMO)<sup>35</sup>. Furthermore, in July 2016, the international expert panel set up by the Commission to perform a Mid-Term Review of EUROfusion, concluded that *'In relation to the scientific and technical work, the Panel considers that this has largely continued as planned with a high proportion of milestones and deliverables being achieved, and with some notable successes in this period – the experiments with metal/ITER-like walls on medium sized tokamaks and JET, the completion of the construction of Wendelstein 7X and its start-up, and the introduction of a new supercomputer for fusion modelling studies'*. Table 11 provides an overview of main results expected from fusion research funded by the Euratom Programme and Annex 4 provides an overview of important scientific achievements in 2016.



#### Public consultation: fusion research

Stakeholders commented on the effectiveness of Euratom-supported fusion research as part of the public consultation carried out during the Interim Evaluation of the Euratom Programme 2014-2018. Only 5.3% of respondents thought that the Euratom programme was not making progress towards delivering its objectives in fusion research.

#### 7.1.2. Publications in peer-reviewed journals

**The number of published papers in high quality peer-reviewed journals remains consistent with the level during the previous European fusion programme in FP7, once**

<sup>34</sup> Milestones have been defined in the co-fund grant agreement with the EUROfusion consortium.

<sup>35</sup> Annex 5 to the Report from the Commission Expert Group provides a list of technical achievements during the period 2014-2016 in each Mission.

allowance is made for the new programme structure. The previous programme included 26 Contracts of Association with national fusion labs, thus effectively ensuring that all fusion research funding in Europe was linked with the Euratom programme. However, from the start of 2014, only approximately 1/3 of national funding has been channelled through EUROfusion. Therefore one cannot compare directly the number of published papers. In reality, the figures since 2014 would be expected to be c. 1/3 to 1/2 of the historical figure during the period of the 26 Associations, when on average some 800 papers were published per year. This is borne out by the statistics in the table 6 below.

2014 was the first year of EUROfusion, and many papers with the EUROfusion logo would not have appeared until 2015 in view of the time needed to go through the publication procedure. In addition, the somewhat fewer papers published in 2016 than in 2015 is most likely due to an artefact of the conference cycles, with international conferences such as the IAEA's FEC (Fusion Energy Conference) occurring only every two years on even-numbered years (in the autumn). Therefore, in 2015 many papers were published as a result of the 2014 conferences, and this is likely to be seen also in a spike in 2017.

Table 6 The number of fusion research publications in peer-reviewed high impact journals			
2014	2015	2016	2017
200	450	325	Not available yet

Source: Web of Science

### 7.1.3. Joint exploitation of European fusion research infrastructures

The JET facility at Culham, UK, is the operational fusion device that is closest to ITER in design, meaning that JET plays a crucial role in deciding design choices for ITER and in the preparations for ITER exploitation. This was further reinforced thanks to the all-metal 'ITER-like' inner wall installed on JET in a major refit in 2009-2011, and **the current scientific exploitation of JET by the EUROfusion consortium is therefore fully able to support the ultimate success of ITER, through investigating ITER plasma scenarios and mitigating ITER operational risks in ITER-relevant conditions.** Indeed, early experimental results from JET following restart after the installation of the 'ITER-like' wall challenged our understanding of the behaviour of plasmas in 'all metal' tokamaks. Technical problems at JET in 2014 & 2015 prevented the carrying out of further cutting-edge research for several months, but these problems have now been resolved and the latest experimental campaign in autumn 2016 was very successful, with JET operating at almost full power and enabling significant progress to be made on improving plasma performance in 'all metal' tokamaks. The fusion research community is confident that remaining plasma performance issues can now be resolved before ITER becomes operational. This will accelerate start of ITER scientific exploitation and enable significant cost savings by shortening preparatory phase - each year of additional exploitation of ITER would cost on average ~EUR 250 million/year (2015 prices), of which Euratom would need to contribute on average ~EUR 85 million (equivalent to 34% of the operating costs, the agreed Euratom share).



<b>Table 7</b> <b>The number of researchers having access to fusion research facilities through Euratom Programme support</b>		
2014	2015	2016
872	958	1039

*Source: annual reports from EUROfusion*

In EUROfusion, it is not only JET that is exploited but also other key 'medium-sized' tokamaks (MSTs) and linear plasma devices in other European countries (e.g. ASDEX-Upgrade at IPP, Germany, TCV at EPFL, Switzerland, and now W7-X at IPP Greifswald, Germany, with MAST-Upgrade at CCFE, UK, due to be co-exploited from 2017).

Until the end of Euratom FP7 (2013) the exploitation of these devices, although supported by Euratom, was under the responsibility of their home laboratories. Bilateral collaborations were in place and exchange of personnel was supported through Euratom mobility funds. Now, under the Euratom Programme 2014-2018, a substantial part of the experimental programme is carried out under the EUROfusion responsibility, in a way similar to the exploitation of JET. The experimental programme is discussed collectively and implemented under the responsibility of the relevant EUROfusion Taskforce Leaders and Project Leaders.

The Commission Expert Group concluded that the **main advantage of the new system is the more effective integration of the experimental programmes of the various facilities. This allows an optimal allocation of tasks to the various European facilities (JET, MSTs and plasma-wall interaction devices) through the selection of the facility best suited for the execution of each task.** The execution of the programmes has been harmonised, for example in joint planning meetings, to allow the participation of key scientists to each task. The view of the Group is that this approach has substantially increased the added value of the Euratom contribution.

This joint programming approach is central to the EUROfusion ethos. The related access and mobility of researchers (see table 7), together with the dissemination and sharing of results, are assured through the joint programme, once again underlining that the fusion research programme is the best example that Europe can offer of ERA – the 'European Research Area' – in action.

One of the latest additions to the group of world-beating fusion research devices in Europe is the Wendelstein7-X (W7-X) stellarator, located at IPP, Greifswald in Germany. The construction of this cutting-edge facility was co-funded in the initial phase by Euratom programmes in the past, and W7-X has now been fully integrated into the EUROfusion joint programme following successful commissioning and the 'first plasma' achieved in December 2015, with access assured by researchers from across Europe as part of this programme.

#### *7.1.4. Fusion education, training and mobility*

One of the principal objectives of EUROfusion and the Euratom Programme is to ensure the availability of appropriate human resources in the fusion research effort over the longer term,

in particular in view of the need to train an 'ITER generation' of scientists and engineers to operate and exploit ITER, and to ensure the right balance and competences of physicists and engineers in a DEMO programme focusing increasingly on CDA (conceptual design activity) and EDA (engineering design activity) over the course of the next 10-15 years. In 2005, a major survey of the HR requirements of the fusion programme was carried out by the Commission with the support of EFDA and the national labs, and this was updated in 2015 under EUROfusion, again with Commission support. Issues such as PhD and Masters programmes, role of FuseNet<sup>36</sup>, training instruments, numbers of researchers, physicists, engineers and technical staff needed in the programme, role of industry, gender balance, etc. were all covered in the survey, with particular focus on the evolution since the 2005 survey. A number of recommendations were issued, which have since been taken up by EUROfusion, though other stakeholders (FuseNet, labs, F4E, industry) are also concerned. FuseNet is a key actor in this field, and efforts are now on-going within EUROfusion to reinforce FuseNet's role through ensuring linked third party status within the joint programme. The Commission will continue to monitor the situation, in consultation with the EUROfusion, and may propose further actions as part of future Euratom programmes and/or amendments to the EUROfusion Grant Agreement.

One of the tasks of the EUROfusion consortium is to support PhD students in the research institutions working on fusion-relevant thesis subjects, i.e. mainly on fusion plasma physics and engineering. Both magnetic confinement fusion and inertial confinement fusion are covered, but 90% of the funding is earmarked for the former. The allocation of funding to individual research institutions is based on the number of students and theses supported each year (weighting 65%) and a quality assessment of the student training provided (weighting 35%). Furthermore, the thesis subjects are screened by EUROfusion to ensure they are relevant for the fusion roadmap implementation. Table 8 shows the evolution of the budget for PhD students and number of active students for each year. About 24 % of on-going PhDs are technology related and women account for 15% and 18% of all PhDs (technology and physics respectively). **Current data shows positive trend in number of PhDs which should allow keeping the manpower of fusion programme at current level<sup>37</sup>.**

Table 8: EUROfusion support for PhD studies: evolution of budget (Mio EUR) and number of PhD students			
Year	2014	2015	2016
Budget for PhD studies	9,000	7,868	7,908
Number of PhD students	658	713	756

Source: Annual reports from EUROfusion

Fusion research and technology development requires staff with skills going beyond PhD level. For this reason and in order to maintain highly qualified staff, EUROfusion has set up

<sup>36</sup> For more info <http://www.fusenet.eu/>

<sup>37</sup> Conf. recommendation 21 of the Review of Human Resources in the European Fusion Landscape (March 2016)



EUROfusion Researcher Grants (ERG) and EUROfusion Engineering Grants (EEG). The ERG are post-doc grants to scientists who have recently finalised their PhD, while EEG aims to encourage excellence and career development of young engineers. Support for EEG grants is constantly adjusted to the expected shortage of skills in specific missions of the fusion roadmap. Current data (table 9) shows positive trends in number of grants awarded. Since the first grantees are roughly halfway through their contract, it is premature to elaborate on the outcome and success rate of the ERG and EEG. But given the success of similar grants awarded under Euratom FP7, it is to be expected that many of the grantees will stay in fusion research.

<b>Table 9 - EUROfusion training actions</b>				
	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>Total</b>
The number of researcher grants awarded per year	17	11	11	39
The number of engineering grants awarded per year	-	17	20	37
<b>Total</b>	17	28	31	76

*Source: Annual reports from EUROfusion*

Mobility of researchers and scientists within the joint programme is one of the cornerstones on which the success of EUROfusion depends. Mobility support covers funding for visiting scientists for joint research, long-term secondees, and fellowships. Within EUROfusion, mobility for joint research activities is approved in line with the project-oriented approach and is directly integrated into the programme budget and managed under the responsibility of each Project Leader and Taskforce Leader.

The Commission Expert Group concluded that short-term mobility has become more clearly focused on the implementation of the roadmap. However, mobility support appears to be overwhelmingly concentrated on the physics side of EUROfusion's activities (e.g., experimental campaigns at JET and the medium-sized tokamaks). In addition, as in previous Euratom programmes, mobility remains important as a means to creating scientific networks between the various national research labs involved, particularly in view of the often fragmented and geographically dispersed project teams.

The issues regarding long-term mobility (e.g. secondments) within the programme are quite different from those of shorter-term mobility. The Unit Cost Decision<sup>38</sup> provides the basis for the supplementary remuneration of secondees to the Programme Management Unit (PMU), ensuring a level playing field for all labs and secondees from across Europe (to the extent possible in view of the various tax regulations in force across Member States, which are not under Commission competence). However, experience has shown that the Unit Cost Decision has required additional administrative effort in some laboratories, and in some of the larger labs it is not compatible with normal working practices. On the other hand it has been welcomed in the majority of Member States joining the EU since 2004, who otherwise would not be able to afford the cost of travel.

<sup>38</sup> Commission decision C(2013) 8201 of 10 December 2013

### 7.1.5. Spin offs and patents from Euratom fusion programme

Development of fusion energy requires scientific advances in many different areas which frequently lead to unexpected applications beyond fusion energy. Table 10 shows first spin-offs from fusion research since 2014. In addition, researchers from European fusion laboratories supported by EUROfusion made so far 4 applications for patents.

<b>Table 10 – Recent spin offs from fusion research</b>	
<ul style="list-style-type: none"><li>• Fusion lab in Poland (IPPLM) established in 2014 the Scientific and Industrial Centre for New Energy Technologies (Centrum naukowo-przemysłowe Nowe Technologie Energetyczne (CeNTE). The CeNTE consists of 12 entities: 4 Research Institutes, 7 Universities and 1 business-oriented organisation.</li><li>• Culham Center for Fusion Energy in UK has produced in 2015 the "SPILADY", a computer programme with a spin-lattice dynamics code intended to serve as an introductory computer simulation tool for undergraduate students, scientists, researchers, and interested members of the public familiar with molecular dynamics.</li><li>• MAGICS Instruments NV (MAGICS) is a fusion spin-off company from the University of Leuven, Belgium and SCK-CEN (the Belgium Nuclear Research Centre). MAGICS' core competence lies in the design of radiation hardened integrated circuits, more specifically electronic devices that reliably operate in nuclear environments that yield accumulated doses in excess of Mega Gray. MAGICS addresses customers' demands by offering standard rad-hard products or customized IC design services. The company also provides MGy-level radiation qualification services on its own products or other commercial-of-the-shelf components. (<a href="http://www.magics.tech/about-us/">http://www.magics.tech/about-us/</a>)</li></ul>	

Source: EUROfusion

### 7.1.6. The European Prize for Innovation in Fusion Research (SOFT Innovation Prize)

The European Prize for Innovation in Fusion Research (SOFT Innovation Prize) was first awarded at the international Symposium on Fusion Technology (SOFT) in September 2014, with the second edition awarded at the following SOFT in September 2016. The SOFT Innovation Prize has been promoted by the Commission through the respective Euratom Work Programmes, with the support of the SOFT organising committees, and is a recognition prize highlighting and rewarding excellence in innovation in fusion energy research as well as the quality of the researchers and industries involved. The objective of the SOFT Innovation Prize is to reward outstanding researchers and industries in the search for innovative solutions to challenging problems, possibly with wider applications outside fusion. This promotes and supports innovation in a range of future technologies of importance in the fusion sector, and contributes to the spin-off applications of these technologies in other fields, with potential impact on jobs and growth.

The first edition of the SOFT Innovation Prize in 2014 was limited to EU member states (and Switzerland). Since the 2016 edition, applicants have been welcomed from all ITER parties plus other third countries with Euratom fusion bilateral agreements (Ukraine, Kazakhstan and Brazil). A participant can be a researcher, a research team or an industry. The 2016 edition saw more applicants, and a higher quality of submissions, including one from outside the EU (China). In 2016, three prizes were awarded: 1st prize: 50 000 EUR, 2nd prize: 25 000 EUR and 3rd prize: 12 500 EUR. Prizes are awarded during the SOFT conferences, which every two years gather about 800 participants from all over the world active in universities, research laboratories and in industries. The SOFT is the largest technology-oriented fusion event in the world, offering scientists, engineers, developers, manufacturers and students the opportunity to exchange views, visions and experiences and to establish contacts.

In 2016 SOFT Innovation Prizes were awarded to a partnership from the Karlsruhe Institute of Technology (KIT) and Ecole Polytechnique Fédérale de Lausanne, a partnership from ENEA and CEA, and a young researcher from CCFE. The technologies were respectively a new type of high temperature superconducting cable, an innovative membrane to produce ultra-pure hydrogen, and cutting-edge VR software to improve radiation protection during access to contaminated areas.

**Thanks to the SOFT Innovation Prize, the winning researchers have had good visibility and the innovation aspects of the fusion programme as a whole have also been put in the spotlight. Some of the projects have also filed patents, which could raise the interest of European industry.** The prize also raises awareness among fusion researchers in general on the importance of entrepreneurship, patents, market readiness and spin-offs. Annex 3 provides more details of the prize winning projects.

<b>Table 11 - Expected main outputs and results of Euratom Research and Training Programme 2014-2018</b> <i>(on the basis of description of work for projects launched until September 2017 and Work Programme 2018)</i>			
<b>Fusion</b>	<b>Nuclear Safety</b>	<b>Waste Management</b>	<b>Radiation Protection</b>

<p><b>Integration of research:</b> launch of European Joint Programme, update of fusion roadmap.</p> <p><b>Development and qualification of plasma regimes of operation for ITER and DEMO (Mission 1)</b></p> <ul style="list-style-type: none"> <li>- Further optimisation of plasma regimes of operation with metallic wall;</li> <li>- Further development of mitigation and control of disruption and runaway electrons;</li> <li>- Control of plasma edge instabilities;</li> <li>- Establishment of regimes of operation with high radiated power;</li> <li>- Enhanced predictive capabilities of fusion plasma performance by numerical simulations and validation of models.</li> </ul> <p><b>Development of heat exhaust systems (Mission 2):</b></p> <ul style="list-style-type: none"> <li>- Demonstration of significant reduction of tritium retention in plasma facing materials;</li> <li>- Completion of a preliminary design and technology development for the divertor;</li> <li>- Definition of the scope and feasibility of a divertor tokamak test facility.</li> </ul> <p><b>Development of neutron resistant materials (Mission 3):</b> Substantial progress in the qualification of the neutron resistant materials and in increasing their working temperature range.</p> <p><b>Development of components to ensure tritium self-sufficiency (Mission 4):</b> Substantial progress in the design of the four breeding blanket concepts.</p> <p><b>Implementation of the intrinsic safety features of fusion into the DEMO design (Mission 5):</b> Definition of the safety and licensing requirements.</p> <p><b>Integrated DEMO design (Mission 6&amp;7):</b> Pre-conceptual DEMO design activity, preparation of the Stakeholder and Plant Requirements document. DEMO-relevant samples of superconducting magnets fabricated and tested. Significant progress in the remote maintenance.</p> <p><b>Stellarator development (Mission 8):</b> Commissioning and operation of the W7X facility.</p>	<p><b>Safety of existing Nuclear power plants:</b></p> <ul style="list-style-type: none"> <li>- Better understanding of physical processes involved in nuclear reactors' anomalies and development of a non-intrusive innovative core-monitoring technique for detection and characterisation of anomalies;</li> <li>- Progress in development of accident-tolerant fuels;</li> <li>- Improved assessment techniques of structural integrity of nuclear power plants' components;</li> <li>- Better understanding of the ageing phenomena occurring in reactor pressure vessel steels. Development of predictive approaches in support of surveillance programs;</li> <li>- Establishment of a procedure for fatigue analysis in NPPs based upon experimental test data, integrating also impact of environmental effects;</li> <li>- Development of mitigation techniques for environmentally-assisted cracking of nuclear power plants components;</li> <li>- Improvement of the detection limits of the ultrasonic inspection techniques of complex structures;</li> <li>- Development of non-destructive evaluation tools for characterisation of the embrittlement level in reactor pressure vessels;</li> <li>- Updated elements for Probabilistic Safety Assessment of Nuclear Power Plants focusing on external natural events like earthquake, tsunami, flooding, high speed winds, etc.;</li> <li>- Further development of in-vessel retention of melted core;</li> <li>- Update and validation of simulation tools to improve accident management and emergency response;</li> <li>- Development of a backup cooling system to upgrade LWRs passive safety systems.</li> </ul> <p><b>Future nuclear power plants:</b></p> <ul style="list-style-type: none"> <li>- Improved modelling and safety assessment of different future reactor concepts;</li> <li>- Improvement of nuclear fuel cycles for advanced systems;</li> <li>- Qualification of structural materials for future nuclear systems;</li> <li>- Testing of safety features and waste management of future concepts;</li> <li>- Conceptual design for a high Temperature nuclear cogeneration system to supply process steam to industry – licencing framework and business plan for full scale demonstration.</li> </ul>	<p><b>Integration of research:</b> establishment of a European Joint Research Programme in the management and disposal of radioactive waste.</p> <p><b>Geological disposal of HLW &amp; SF:</b></p> <ul style="list-style-type: none"> <li>- Development of means and conditions for a sustainable network of independent technical expertise for safety case reviews;</li> <li>- Improved knowledge on the impact of cement materials in contact with bentonite barriers and the host rocks on the mobility of radionuclides;</li> <li>- Assessment of the impact of microbial metabolisms on the safety of geological repositories;</li> <li>- Development and demonstration of monitoring strategies &amp; technologies for geological repositories;</li> <li>- Development of tools for the assessment of the bentonite barriers mechanical evolution;</li> <li>- Improved understanding of the dissolution and chemistry of modern spent fuels in failed container conditions.</li> </ul> <p><b>Management of other radioactive waste:</b></p> <ul style="list-style-type: none"> <li>- Development and validation of new techniques for the characterization of conditioned radioactive waste;</li> <li>- Assessment of thermal treatment technologies providing waste volume reduction.</li> </ul> <p><b>Decommissioning:</b></p> <ul style="list-style-type: none"> <li>- Development of a roadmap for decommissioning research aiming at safety improvement, environmental impact minimisation and cost reduction;</li> <li>- Development of methodologies for more accurate estimation of the characteristics and the volume of contaminated materials as well as for improved Decommissioning and Dismantling (D&amp;D) planning.</li> </ul>	<p><b>Integration of research:</b> establishment of European Joint Programme in radiation research (CONCERT), implementation of Strategic Research Agenda, implementation by CONCERT of a portfolio of projects in radiation protection;</p> <p><b>Nuclear emergency preparedness:</b> Development of improved nuclear emergencies modelling for atmospheric dispersion, dose estimation, food chain and countermeasure simulations and their propagation in decision support systems</p> <p><b>Radiation biology:</b> better understanding of low dose radiation induced effects at molecular, cellular and tissue level</p> <p><b>Radioecology:</b> preparation of novel guidance documents for dose assessment, risk management, and remediation of radioactively contaminated sites</p> <p><b>Supply of medical radioisotopes:</b> In order to maintain supply chain of medical radioisotopes, development of a new, safe, high-density fuel for high performance research reactors while addressing proliferation concerns.</p> <p><b>Medical low dose radiation exposure:</b> Contribution to refined radiation protection in the medical field by: i) improving organ dose estimation, ii) evaluating the effects of low to moderate doses of radiation, with a focus on cardiovascular disease as a result of radiotherapy and cancer risk as a result of CT scans, and iii) formulating a series of evidence-based recommendations to improve radiation protection of patients, medical workers and general public.</p>
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## 7.2. Effectiveness of Euratom supported fission research

Following three calls for proposals (2014/15 and 2016/17), the Commission launched 48 projects and other actions which address specific objectives in nuclear safety, waste management and radiation protection set by the Council Regulation establishing the Programme (see table 12). The first 23 projects were launched in 2015 following signature of the grant agreements. The second group of 25 projects (including 2 cross-cutting fission-fusion projects) were launched in June 2017. In view of the recent launch of these fission projects, this interim evaluation is based on limited feedback. The Commission has only recently received first periodic reports from the projects launched in 2015, and in the case of projects launched in 2017, the Commission services have at their disposal only the descriptions of planned research work.

Nonetheless, the currently available data as well as the report from the Commission Expert Group confirm that **the scope of the 48 projects supported by Euratom addresses the objectives set by the Council Regulation in the specific area of fission research**. The 23 projects in the field of nuclear safety represent 48% of all projects, the total Euratom contribution to these projects accounting for 41% of the total budget for fission R&D during the period 2014-2017. Projects in nuclear safety support research on existing Nuclear Power Plants as well as the safety aspects of future designs. The 2<sup>nd</sup> area of research in terms of Euratom expenditure (22% of the total) concerns support for research infrastructures, including the access to Jules Horowitz Research Reactor and InnovFin loans for fission research infrastructures in general (loans to be available from 2017).

**Table 12 – Euratom funding and number of projects launched in fission and distribution per specific objective during 2014-2017 (in Euro)**

	<i>Nuclear Safety</i>	<i>Waste Management</i>	<i>Nuclear expertise and excellence</i>	<i>Radiation Protection</i>	<i>Innovation</i>	<i>Infrastructures</i>	<i>Social aspects</i>	<b>Total</b>
<b>Work Programme 2014-2015</b>								
<b>Projects</b>	35,046,832.86 <b>9 projects</b>	16,303,167.25 <b>5 projects</b>	3,552,269.00 <b>2 projects</b>	19,822,878.00 <b>1 project (EJP)</b>		10,087,286.00 <b>2 projects</b>	5,331,899.00 <b>4 projects</b>	90,144,332.11
<b>Other actions</b>						15.000.000 (support for access to JHR)		15.000.000
<b>Total</b>	35,046,832.46	16,303,167.25	3,552,269.00	19,822,878.00		25,087,286.00	5,331,899.00	105,144,332.11
<b>Work Programme 2016-2017</b>								
<b>Projects</b>	59,708,662.80 <b>14 projects</b>	19,455,488.90 <b>5 projects</b>	9,096,239.25 <b>3 projects</b>	9,995,145.75 <b>1 project</b>	3,999,259.69 <b>1 project</b>	6,598,148.25 <b>1 project</b>		108,852,944.64
<b>Other actions</b>						20,000,000.00 (Innovfin for Euratom)		20,000,000.00
<b>Total</b>	59,708,662.80	19,455,488.90	9,096,239.25	9,995,145.75	3,999,259.69	26,598,148.25		128,852,944.64
<b>Total for 2014-17</b>	<b>94,755,495.26</b>	<b>35,758,656.15</b>	<b>12,648,508.25</b>	<b>29,818,023.75</b>	<b>3,999,259.69</b>	<b>51,685,434.25</b>	<b>5,331,899.00</b>	<b>233,997,276.75</b>
<b>% of budget 2014-17</b>	<b>41%</b>	<b>15%</b>	<b>5%</b>	<b>13%</b>	<b>2%</b>	<b>22%</b>	<b>2%</b>	<b>100%</b>

Source: European Commission

Table 13 shows progress made by fission projects in three main areas of research (safety, waste management and radiation protection). While the number of reported publications is relatively low at the start of project implementation, it can be noted that Euratom projects already established substantial teams of researchers (almost 1200 people) and they report progress made in terms of milestones reached. Table 11 shows a summary of expected impacts of the Programme in the above fields.

In order to assess the effectiveness of the fission part of the Euratom programme, a survey of participants in Euratom projects launched under the Euratom 2014-18 programme and FP7 was carried out in 2016. The e-survey questions on effectiveness sought to gather the perception of respondents concerning the extent to which their project(s) produce expected outputs, as defined in the projects' contractual documents, as well as immediate results (e.g. the intermediate stage between outputs produced by the project and impact). **Respondents to the e-survey overwhelmingly reported that their projects had performed or are performing well in terms of producing the envisaged outputs. Overall, more than 85% (544) of the respondents considered that their project(s) produce(d) the expected deliverables,** of which half reported only minor deviations compared to the expected outputs. Less than 3% (16) of respondents considered that the expected outputs were not produced. The remaining respondents considered that it was not possible to answer the question because their projects were still ongoing. No project was considered as unable to deliver its planned outputs by a significant number of respondents.

According to qualitative responses received from respondents, deviations most often arose from the natural uncertainty and unpredictability of the scientific process. Major causes reported by e-survey respondents were technical difficulties encountered (e.g. equipment failure) and unexpected challenges or outcomes in experimental activities, which require an adjustment in the direction of the project. Collaborative and focused research projects are most susceptible to these types of problems. Other issues cited as impacting effectiveness in a small number of cases included administrative delays, a lack of interest from key target groups in some projects, or difficulties in the collaboration between partners.

More generally, the e-survey also asked respondents to indicate any difficulties that had been experienced in the implementation of their projects, whether or not these resulted in major deviations in terms of project deliverables. 33% of the respondents (254) did not identify any difficulties during the implementation of their projects. The remaining 67% indicated at least one difficulty, though a range of reasons were mentioned and no clear pattern has emerged. The main difficulties underlined are external delays (25% of the difficulties) and budget limitations (24% of the difficulties), followed by the lack of engagement of project partners (17%), internal events (12%) and the feasibility of the project (8%). 15% of the responses (75 respondents) described other types of difficulties, mainly inadequately defined work plans, technical difficulties and lack of coordination and communication. The high number of respondents pointing to budget limitations and the citing poorly defined work plans does raise some concern that projects are not adequately defined and budgeted for at the stage of the



proposal and that more scrutiny on this aspect may be needed during the proposal evaluation process.

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<b>Table 13 – Data from first periodic reports of fission projects launched in 2015</b> <i>(Data retrieved in February 2017)</i>											
Field of research	Scientific publications (all)	Scientific publications (peer reviewed)	Audience reached by projects			Researchers involved in projects			Number of SMEs in projects	Milestones reached by project	Average duration of the project
			Industry	Civil society	Scientific community	Male	Female	Total			
Nuclear safety (9 projects)	22	16	406	25	2132	366	98	464	9	67%	45.6
Nuclear waste management (5 projects)	13	2	920	190	2000	290	165	455	8	91%	42
Radiation protection (1 project)	n/a	n/a	n/a	n/a	n/a	129	145	274	n/a	44%	60
<b>Total</b>	35	18	1326	215	4132	785	408	1193	17		49

*Source: European Commission, periodic reports from projects*

### 7.3. Impacts of the previous research and training programme – Euratom FP7 and comparison with the expected impacts of Euratom programme 2014-2018

#### 7.3.1. Impacts of Euratom FP7

The Euratom 7<sup>th</sup> Framework Programme (FP7)<sup>39,40</sup> was implemented during 2007-2013 and was subject of an ex-post evaluation carried out by independent experts<sup>41</sup> in 2015 (see COM(2016)5 and Annex 1 in particular). FP7 impacts can be summarised as follows:

- In *fission research*, research supported by Euratom FP7 had a substantial number of scientific achievements in all fields supported by the programme - nuclear safety, radiation protection, radioactive waste management. A substantial number of research proposals (286 proposals submitted for seven annual calls) prepared by 3354 applicants demonstrated a strong interest of research stakeholders to participate in nuclear research at European level. Stakeholders, including industry, have also shown a readiness to form consortia in response to the calls - the average consortium size in Euratom Programme was significantly higher than across FP7 as a whole (17 compared to 12 partners per collaborative project). Moreover, total investment in funded projects was almost €660 million for a Euratom contribution of only €354 million (54% of total costs).
- Euratom FP7 activities *in nuclear safety* have concentrated on research in severe accidents, long-term plant operation (i.e. ageing and integrity of various materials and components), plant safety simulation tools and the man-machine interface.
- Euratom funded projects, such as SARNET-2, contributed to the resolving of important pending issues on postulated severe accidents of existing and future nuclear power plants (e.g. severe core damage and resulting release of radiation in the event of ‘beyond design basis’ events). These projects optimised use of available resources in this field and established a sustainable network to support the development of joint research programmes and a common computer tool to model and predict Nuclear Power Plants behaviour.
- Regulatory authorities in many countries are approving lifetime extensions of nuclear power plants (NPP) beyond original design lifetimes. The key consideration in granting an extension to the operation license is the degradation over time (thermal cycling, irradiation damage, other chemical / physical processes) of materials and components with a safety function. A number of Euratom FP7 projects have focused on such issues and related management of safety-related functions (e.g. projects PERFORM-60, LONGLIFE, STYLE, ADVANCE). The projects are developing and improving tools for predicting the combined effects of irradiation and corrosion on key components such as the reactor

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<sup>39</sup> [Council Decision 2006/970/Euratom of 18 December 2006 concerning the Seventh Framework Programme of the European Atomic Energy Community \(Euratom\) for nuclear research and training activities \(2007 to 2011\)](#) includes a budget of EUR 2 751 million to be spent over five years (2007-2011).

<sup>40</sup> [Council Decision 2012/95/Euratom of 19 December 2011 concerning the Seventh Framework Programme of the European Atomic Energy Community \(Euratom\) for nuclear research and training activities \(2012 to 2013\)](#) includes a budget of EUR EUR 233,2 million to be spent over two years (2012-2013)

<sup>41</sup> Report available on [https://ec.europa.eu/research/evaluations/index\\_en.cfm](https://ec.europa.eu/research/evaluations/index_en.cfm)

pressure vessel, and for the structural integrity assessment of the cooling circuit. Importantly, the projects are establishing a common and harmonised set of tools and methods for use in all reactor lifetime assessments and related predictions in Europe.

- Several Euratom research projects addressed issues raised by Fukushima accident. Specific projects have been launched addressing hydrogen issues in the containment (ERCOSAM project), containment venting technology (PASSAM), modelling tools for severe accidents (SARNET2 and CESAM), PSA methodologies for assessing extreme external events (ASAMPSA\_E), and assessment of in-vessel and ex-vessel phases of a severe accident (SAFEST and ALISA). In addition, accident consequences for health and the environment, including marine radioecology, were investigated by projects DOREMI, STAR, PREPARE, COMET, and NERIS-TP under the topic of radiological and emergency preparedness.
- In *radiation protection*, the Euratom Programme supported the development of a comprehensive, state-of-the-art, science-based evaluation of radiation risks in low-dose research and has had a large impact in terms of publications and training of a new generation of researchers in radiation protection. Euratom projects have substantially contributed to the optimisation of the use of radiation in medical applications. For example, significant advances in the use of radiation in medicine achieved by FP7 help cut down exposures to patients which reduces the recovery time and the chance that secondary cancers occur, as well as the exposure to medical staff. Because of the growing use of new medical diagnostic procedures such as computed tomography (CT) and positron-emission tomography (PET), medical exposure to radiation of the population has increased rapidly in recent years. Euratom projects have substantially contributed to the optimisation of the use of radiation in medical applications by developing innovative products and algorithms in 3D nuclear medical imaging and breast imaging (projects MADEIRA & Breast-CT), for better diagnostics, optimised patient-dose calculation and application, and higher resolution images. By enabling earlier and more accurate diagnosis, these innovations will help to increase survival rates and reduce the high costs of cancer treatment.
- The most important development in the area of low-dose research was the launch the Multidisciplinary European Low-Dose Initiative (MELODI). This would not have been possible without the funding and support of the Euratom Framework Programme. This initiative, since evolving into a legal entity under French law, has developed a clear vision for future radiation protection R&D and a related Strategic Research Agenda (SRA), which brings together the full range of necessary disciplines and competencies thanks to its large stakeholder base. SRAs in related sectors such as radioecology have also been developed thanks to other Euratom projects. All these projects have helped retain European competences in technical sectors or growing importance worldwide.
- *Emergency management and rehabilitation* have also been greatly improved in Europe as a result of Euratom FP7 projects that have integrated Member States' capabilities as well as providing practical information and documentation for improved guidance regarding post-accident response and clean-up.
- *Managing radioactive waste safely* is a concern for all EU Member States, whether it relates to the waste from nuclear electricity production or from radiation use in research,

industry and medicine. Following more than 30 years of research co-funded by Euratom, geological disposal now represents a passively safe and sustainable option for the long-term management of nuclear waste. Euratom projects launched during FP7 have contributed substantially to the overall progress in the development of geological disposal of nuclear waste. Euratom projects have redefined the state of the art in main areas: knowledge base and tools for safety assessment of waste repositories, development of repository technologies (demonstration activities by LUCOEX project), and public involvement – projects such as IPPA, INSOTEC provided a neutral forum for discussion between all concerned stakeholders, including local communities, enabling progress in actual disposal programmes. Decisions regarding disposal of radioactive waste are taken at the national level and should be based on a sound understanding of the scientific and technical issues and related risks.

- In *fusion research*, one of the scientific and technical achievements was the completion of the ITER-Like Wall (ILW) upgrade of JET facility (2009-2011). This established the JET tokamak as the only device worldwide that uses the same combination of plasma-facing components as those to be used in ITER. It involved replacing more than 4000 internal tiles by remote handling. The ITER-Like Wall in JET has since yielded many important results. In particular, results confirmed that ITER could be fitted with a tungsten divertor from the start of its planned operation, avoiding the need for an initial carbon divertor and representing significant cost savings for the project as a whole. Furthermore, JET experiments with the ILW have revealed many new aspects associated with operating with a metallic wall.
- *Contribution to the scientific excellence of nuclear research in Europe*: During 2007-2013 scientific outputs of the Euratom Programme in fusion research have been substantial. Results have been published in more than 5000 internationally reviewed articles. The average number of peer-reviewed publications per annum in journals from European fusion associations over the FP7 period was 665. This represents an almost 20% increase over the FP6 period. The total number of citations – a measure of the impact of the work – has increased even more strongly: an average of over 8600 citations per annum during FP7 compared with around 2200 under FP6. In nuclear fission, 103 completed projects (out of 134 launched during FP7) resulted in 947 publications in peer-reviewed journals, of which 211 were published in high impact journals.
- *Support for the development and sustainability of nuclear expertise and excellence in Europe*: Effective transfer of knowledge, skills and competences from the current generation of nuclear experts to the next is indispensable for ensuring nuclear safety and radiation protection across Europe, as well as developing fusion. In nuclear fission, 73 completed FP7 projects (out of 134 in total) involved 520 PhD students, of which 33% were female. This indicates that on average, each project supported more than seven PhD students. In fusion, the Goal-Orientated Training (GOT) programme and researcher fellowships funded by Euratom have successfully contributed to supplying fusion research with urgently needed new fusion engineers (160) and researchers (24). Euratom supported also a mobility scheme, facilitating movement of researchers across Europe. In Euratom FP7, the number of researchers participating has generally increased from around 600 in 2006 to 1100 in 2013. JET facility has provided a key focus for mobility of scientists and

European integration, operating as a truly international collaboration with participation from across the EU and beyond. During FP7, 958 scientists made visits to JET to undertake research, many of these visiting more than once.

- The Euratom FP7 has shown a clear European added value in this field. The Euratom programme mobilised a wider pool of excellence, competencies and multi-disciplinarily than is available at national level. The achievements of the fusion programme, in particular resulting from joint exploitation of JET, rely on the collective endeavours of researchers and engineers from across Europe (about 350 persons per year), supported by Euratom funding for mobility. In fission area, projects in nuclear safety and radiation protection ensured that competences in key technical sectors can be retained in Europe, requiring the bringing together of expertise from many Member States, and the establishing of legal entities to ensure sustainability in the long term. The Euratom programme increased the willingness of research stakeholders to release capital for projects with particular importance for nuclear safety. The SARNET-2 project is an excellent example of the leverage effect of Euratom funding – the total budget was almost €39M but the Euratom contribution is just €5.75M (i.e. less than 15% of total costs). The project supported 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 defined joint research programmes and developed common computer tools and methodologies for safety assessment of nuclear power plants, and ultimately supported efforts for sustainable integration of the key R&D organisations in this sector.

### *7.3.2. Comparison of Euratom FP7 and Euratom programme 2014-2018*

Progress achieved so far by the Euratom Programme 2014-2018 (see sections 5 and 7) shows that the programme is on track to achieve its objectives. The main difference with the implementation of Euratom FP7 is that the 2014-2018 Programme implements some research actions which are channelled through European Joint Programmes. These EJP aim at attracting and pooling a critical mass of national and Euratom resources for achieving significant economies of scales. Apart of Eurofusion for fusion research, this instrument is being implemented in radiation protection, and a Joint Programme is expected to be launched for implementing waste management research. Under Euratom FP7, the fission part of the programme was implemented mainly through research and innovation actions.

## **8. EFFICIENCY OF EURATOM PROGRAMME**

This section provides an evaluation of the efficiency of the Euratom Programme and addresses in particular the new instruments that have been introduced in 2014 such as the European Joint Programmes (EJP). Analysis of the efficiency of the EJP, in particular concerning management and governance, is important since this instrument accounts for 75% of the budget for indirect actions<sup>42</sup>.

### **8.1. Efficiency of European Joint Programmes**

Following entry into force of the new Rules for Participation, the European Joint Programme (EJP) co-fund action instrument was used for the first time in the Euratom fusion programme as the means to finance the EUROfusion consortium. The EJP co-fund Grant Agreement allows considerable flexibility within the consortium to organise and implement research and related activities, with the Commission reimbursing costs on a global basis up to the agreed co-fund rate. In the case of EUROfusion, the reimbursement rate was set at 55% subject to the availability of funds. The consortium has the complete freedom to allocate the Euratom funding to the beneficiaries according to its own internal procedures. In this regard, different activities have different internal reimbursement rates, which often were based on normal practice under previous Euratom programmes (EFDA, Contracts of Association).

Such a large and comprehensive joint programme necessarily requires a complex governance structure and management system. These are established in the Consortium Agreement signed by all beneficiaries, and include a weighted voting system if agreement cannot be reached by consensus.

This governance and management system was subject to an in-depth assessment by Ernst&Young consultancy, under the terms of a service contract with the Commission and as part of the Mid-Term Review of EUROfusion and the Interim Evaluation of the Euratom Programme. The conclusions of the assessment are as follows:

- While the publication of the Roadmap created a need for change to ensure that the fusion research community was structured in the most efficient way for its implementation, the transition to EUROfusion was driven primarily by the Commission and its evolving role within fusion research, rather than a widely perceived need for change within a fusion community accustomed to and comfortable with a system in place for over a half century. However, the Commission's decision to reduce its involvement in the scientific orientation of the fusion research programme as well as the scientific administration, and its desire to externalise most administrative and financial management meant that the status quo was no longer tenable. Moreover, the tools used for the implementation of the fusion programme until end-2013 were relics of Euratom dating back to the 1950s and out of step with any other research community.
- The transition to EUROfusion was necessarily hasty in view of the need to synchronise with the start of Horizon 2020. The Consortium had limited time to put in place a complex

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<sup>42</sup> Grant for EUROfusion (including JET contract) and grant for CONCERT (EJP in radiation protection)

organisation or undertake in-depth reflection of possible improvements. Without the proper discussion and in view of the widespread sentiment that the restructuring was ‘imposed’, the initial focus of Research Units was defensive, i.e. to maintain their position and role rather than capitalise on the opportunities created by this major restructuring. Many aspects of the EFDA system, although widely recognised as not being ideal, were carried over to the current EUROfusion organisational structure.

- Whilst the transition to EUROfusion was not positively perceived in the community, there is recognition amongst stakeholders of the weaknesses of the previous approach to implementing fusion research and a general consensus that the EUROfusion organisational structure offers some benefits.
- **The current organisational structure of EUROfusion is ‘fit for purpose’ to continue to implement the Roadmap into the next programming period.** Any benefits of introducing significant changes to the EUROfusion organisational structure would appear to be outweighed by the ‘friction costs’ naturally generated by enacting such important change.

The E&Y report provides a large number of specific recommendations for EUROfusion management for the improvement of governance and management. On the basis of the E&Y report and its own analysis and interviews, the Commission Expert Group concluded that: *"... to date the Euratom Programme in fusion has been effective as the various activities reflect the priorities of the Roadmap and that the programme is pursuing the activities with the highest impact in the realization of the Roadmap ... The efficiency of the implementation of the research programme needs to be improved. The transition between the EFDA/CoA system and Horizon 2020 took place very rapidly and the new system under EUROfusion is slowly adapting. The governance of EUROfusion is progressing but improvements are necessary to strengthen the approach to project management. The Programme Manager should exercise leadership to ensure the prevention of potential conflicts of interest due to the multiple roles of the beneficiaries."*

The Group made specific recommendations regarding EUROfusion governance, project management, planning and programming in line with the above conclusions. These recommendations are essentially addressed to EUROfusion, and while not bringing into question the basic structure or approach, will require further refinements and evolution of the joint programme in order for it to remain effective going into the next programming period (2021-2025 and beyond), when the focus will increasingly be DEMO CDA and EDA. The recommendations are broadly consistent with the more detailed points made by E&Y in its assessment, and the conclusions of the international panel of experts responsible of the Mid-Term Review of EUROfusion. The Commission will work with EUROfusion over the coming months to ensure all recommendations are addressed satisfactorily, and this will also be an important consideration in the planning for the 2021-2025 Euratom Programme, in particular as part of the ex-ante impact assessment



## 8.2. Efficiency of the Euratom Programme management structures

### 8.2.1. Administrative costs

In line with article 4 of the Council regulation establishing the Programme, the Commission's administrative expenditure for indirect actions shall reach up to 7% on average during the duration of the Euratom Programme and no more than 6% in 2018. Analysis of actual expenditure during 2014-2016 and projections for 2017-2018 shows that these limits will be observed. Data show that the administrative budget for 2014-18 will be ca. 6.7%, and for 2018 it is estimated to reach 5.9%.

### 8.2.2. Management of application and evaluation process

Euratom calls for proposals are managed by DG Research and Innovation. For the period 2014-2016, 3 calls have been organised (two biennial calls 2014/15 and 2016/17, and supplementary call 2014/15 concerning safety aspects of supply of fuel for VVER reactors in EU).

In the first three years of Euratom programme, about 500 distinct higher or secondary education institutions, private companies, research organisations, public entities and others applied for Euratom funding. The expenses related to processes on writing, coordinating consortia and administrative questions vary greatly on the types of proposal, salary level of participants involved, administrative support needed etc. Horizon 2020 studies have shown that depending on their age and position, researchers spend from 5-10% of their time applying for research funding<sup>43</sup>. These and following findings are also applicable to the Euratom programme, which is based on the same rules for participation and therefore the same system for submitting proposals and reporting is used for both programmes. **Three quarters (75%) of the respondents to the simplification survey, with experience in FP7 and Horizon 2020, confirmed that, overall, the processes in Horizon 2020 are much simpler than in FP7.** The survey results on the time spent on preparing proposals are presented in box 1.

#### Box 1: Time spent on proposal preparation

- 52.3% of coordinators in a multi-partner project say that they spent more than 30 days, 32% stated that they spent between 15-30 days preparing a proposal.
- 14.3% of partners in multi-partner projects declare spending more than 30 days, 52.6% that they spend between 15 and 30 days.

Source: European Commission Simplification Survey<sup>44</sup>

In total, the evaluation process involved 77 experts (34 for call 2014-2015, 4 for the supplementary call 2014-2015, 39 for call 2016-2017) who were appointed in accordance with the procedures laid down in the Guide for proposal submission and evaluation of the Horizon 2020 grant manual. In selecting experts, the primary objective was to ensure a high

<sup>43</sup> E.g. see <http://www.eui.eu/Documents/MWP/Publications/20111012MWP-ACOSurveyResearchFunding-Full.pdf>

<sup>44</sup> Available at: [http://ec.europa.eu/research/participants/data/ref/h2020/other/events/survey/h2020\\_simplification-survey\\_final-report\\_en.pdf](http://ec.europa.eu/research/participants/data/ref/h2020/other/events/survey/h2020_simplification-survey_final-report_en.pdf)

level of skills, experience and knowledge in the areas of the call (including project management, innovation, exploitation, dissemination and communication). Under these conditions, special attention was given to achieve an appropriate balance composition in terms of various skills, experience and knowledge, geographical diversity and gender, as well as regarding private-public sector balance. As a result, 15 out of the 77 experts (19%) were women. Out of the 77 invited experts, 30 (39%) came from universities and research institutes public or private, 18 (23%) came from non-research public sector, and 29 (38%) were from private commercial firms. 39 out of the 77 experts (51%) were new experts evaluating fission proposals for the first time. In addition, for each call an independent expert was appointed by the Commission to observe and offer an independent advice on the conduct and fairness of the evaluation sessions, on the application of the evaluation criteria and on ways to improve the process.

<b>Table 14 - Data on number of proposals evaluated in Euratom FP7 and Euratom programme 2014-2018</b>			
<b>Programme</b>	<b>Year</b>	<b>No. of proposals evaluated</b>	<b>Total</b>
FP7	2007	54	274
FP7	2008	38	
FP7	2009	29	
FP7	2010	38	
FP7	2011	48	
FP7(+2)	2012	38	
FP7(+2)	2013	29	
2014-2018	2014-2015	62	136
2014-2018	2014-2015 (supl. call)	4	
2014-2018	2016-2017	70	

*Source: European Commission*



#### **Public consultation: management of the calls by the Commission**

In general, consulted stakeholders are content with the management of the Euratom calls by the Commission services. 65% agreed that time taken to evaluate and select proposals is good or acceptable. 61% was of the same opinion regarding time taken to establish contracts and launch projects. Quality of the feedback received by participants in the evaluation process was considered as good or acceptable by 56% of stakeholders.

#### **8.2.3. Ethics and ethics appraisal of proposals**

All activities funded by Euratom are assessed through the Ethics Appraisal Procedure. Applicants must complete an Ethics self-assessment starting with the completion of an Ethics Issues Table and the proposals above threshold and considered for funding undergo an Ethics Review, carried out by independent ethics experts. After signature of the Grant Agreement (GA) and following the recommendations of the ethics experts or at the initiative of the Commission services, ethics checks are to be undertaken for some of the proposals. The main objective is to ensure adherence to ethics requirements and ethics principles in general. If any substantial breaches of ethics principles, research integrity or the relevant Horizon 2020

legislation are identified, the Commission can carry out an ethics audit or take corrective action pursuant to the provisions and procedures laid down in the GA. The ethics appraisal scheme was the subject of an external audit in 2016 and the report concluded that the Ethics Appraisal process is well designed, comprehensive as well as broad (i.e. going beyond standard research ethics). The Commission services are implementing the recommendations of the audit, including the enhancement of training sessions targeting EC personnel and the recruitment and training of new experts.

In the call 2014-2015, out of 52 proposals, 40 with the possibility of being funded underwent ethics screening performed by external ethics experts. As a result, none of these 40 proposals were considered to raise serious or complex ethical issues requiring a more in-depth analysis through further ethics assessment. Out of 21 retained proposals, 3 received ethics clearance and 18 received conditional ethics clearance. In the supplementary call 2014-2015, which included only one topic, all above-threshold proposals (3) underwent ethics screening performed by external ethics experts, and all received conditional ethics clearance meaning that there were no serious or complex ethical issues requiring a more in-depth analysis.

In the call 2016-2017, all proposals except those with little probability of being considered for funding were subject to an ethics screening carried out by ethics experts. This concerned in total 33 proposals, of which 3 were considered not to involve ethics issues and 30 were identified as involving (one or more) ethics issues, though none was considered to require the 'ethics assessment' needed for only the more serious or complex ethics issues. Out of these 30 proposals, 6 received ethics clearance and 24 received conditional ethics clearance. In all calls, recommendations arising from the ethics screening were taken into account in grant agreement preparation.

#### *8.2.4. Euratom Programme simplification*

From the outset, the Euratom Programme and Horizon 2020 in general were constructed around a simplified<sup>45</sup> architecture, set of rules and procedures, control strategy and funding model. A single set of rules applies to the all research and innovation support provided through EU programmes. In order to ensure coherence of this legal frame with all other EU funding programmes, the rules have been aligned to the Financial Regulation. In parallel, the Commission streamlined, harmonised and accelerated procedures and processes linked to programme and project implementation. The new funding model is based on two main features: a single reimbursement rate and a single flat rate. This represents a major simplification compared to FP7 (see table 15).

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<sup>45</sup> Streamlined ex-ante checks, reduced requirements for work time recording, reduced audit burden, an acceleration of the granting processes and fully paperless proposal and grant management.

**Table 15 – simplification measures for Euratom Programme 2014-18 compared with Euratom FP7**

<b>Simplification measure</b>	<b>Euratom Programme 2014-2018</b>	<b>Euratom FP7</b>
<b>Single reimbursement rate</b>	A single reimbursement rate in a given project, without differentiation between organisation categories or types of activities. The reimbursement rate is up to 100% of the eligible costs for Research and Innovation Actions and up to 70% for Innovation Actions	Reimbursement is determined by a matrix of organization categories and activity types.
<b>Single flat rate</b>	A single flat rate for contributing to the indirect costs. This flat rate of 25% is applied to the direct costs	Indirect costs (overheads) are calculated by four different methods (two flat rate models, depending on the organisation categories; real indirect costs and a simplified method of determining real indirect costs. The real indirect cost options were a considerable source of financial errors.
<b>Fusion research</b>	Co-fund instrument covering all joint R&D and related activities, plus an ad hoc bilateral contract with CCFE for the operation of JET	26 Specific bilateral Contracts of Association with national fusion labs, a multilateral agreement (EFDA) between all labs and the Commission, other multilateral Implementing Agreements under EFDA, a bilateral contract for JET operation, and another multilateral agreement on mobility.

*Source: European Commission*

This simplified funding model put the focus on the costs that are directly related to the project. It is expected: to simplify the financial management of projects through a reduced complexity of the financial rules; to reduce the financial error rate detected in ex-post audits; to increase legal certainty for beneficiaries; to increase the attractiveness and ease of access to the programme, in particular for newcomers, smaller actors, SMEs and industry; and to contribute to the acceleration of the granting processes

**The first three calls of Euratom Programme have shown a significant reduction of the Time to Grant, i.e. time elapsed between the closure of a call and the signature of the Grant Agreement for projects in the main ranked list, from an average of 315 days in FP7 to an average of 229 days in the WP 2016-2017.**

### **8.3. How efficient are the communication and application processes?**

A number of communication activities have been undertaken by the Commission services to attract participation in the Euratom Programme, including 'info days' organised on 28 March 2014 for the call 2014-2015 and on 15 September 2015 for the call 2016-2017.

The Euratom Programme strongly encourages dissemination and exploitation of research results. Project beneficiaries have an obligation to promote funded projects and their results, and communication forms part of the activities expected to generate project impact. To guide communication efforts, the Euratom Programme requires projects to develop and implement a communication plan, which goes beyond the project's own community and includes "the media and the public".

As result, a substantial number of communication activities was undertaken to disseminate and communicate the project results and the knowledge generated. Validated periodic reports from the first 18 months of 13 fission projects show many different types of activities including 7 communication campaigns, 3 conferences, 9 workshops. However, citizens are usually not the most important target group of these activities, but rather a secondary or tertiary audience. Projects stating that they intend to target citizens typically mention websites, newsletters, publications and social media channels as means to reach the general public.

<b>Table 16 – audience reached by fission and fusion projects in 2014-2015</b>		
<i>Scientific community</i>	<i>Industry</i>	<i>Civil society</i>
24 800	8000	1800

*Source: European Commission, periodic reports from projects*

Dissemination of results is usually the responsibility of one of the work packages in each of the projects. For the first 23 projects launched in fission following the 2014-2015 call, as well as EUROfusion, table 16 shows the total audience reached through different channels (conferences, symposia, technical meetings).

## **8.4. How efficient is the distribution of funding?**

### *8.4.1. Success rates*

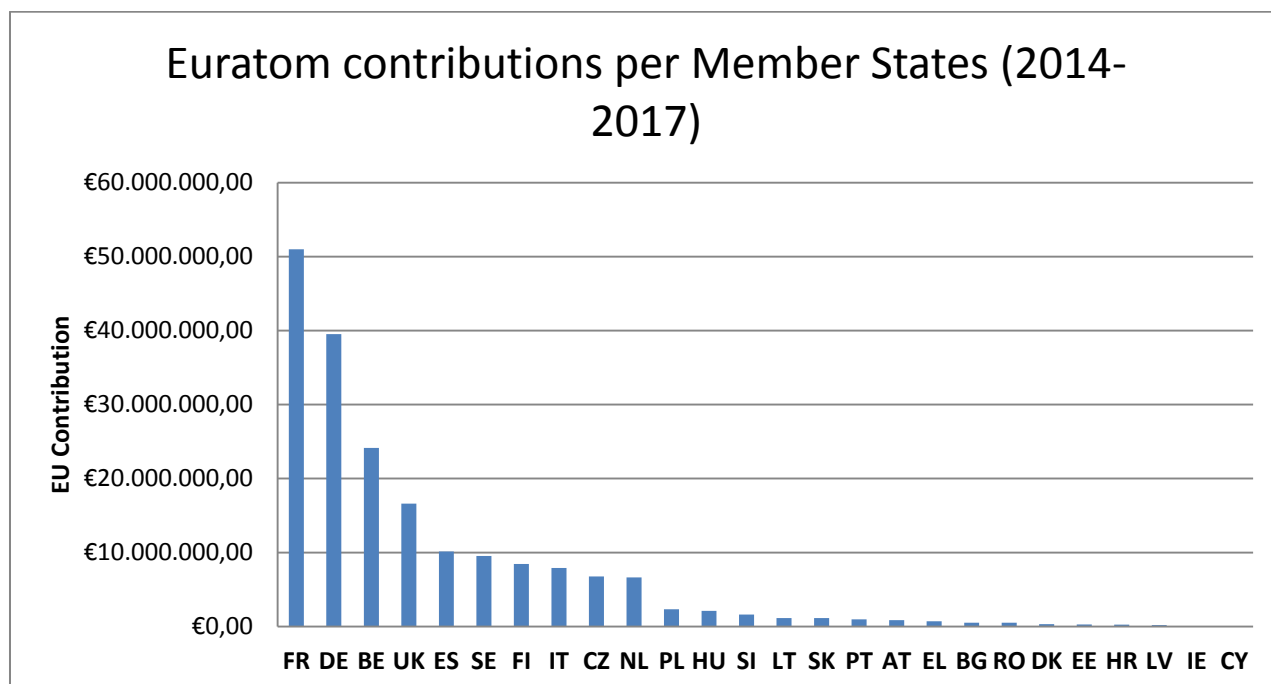
Results of the first fission calls (2014/15) show a very high success rate, with 23 of the 66 eligible and admissible proposals being funded (35% success rate) and 55 evaluated above threshold (83%). Results of the 2016/17 fission call confirm this high success rate, with 23 of the 70 eligible and admissible proposals funded (36% success rate) and 59 above threshold (84%).

**Research stakeholders from NMS are becoming well integrated in European nuclear research.** In fusion research, the participation of smaller fusion labs from these MS was guaranteed as part of the initial 'named beneficiary' approach required by the Council Regulation, and since then most of these smaller labs appear clearly to have benefited from the evolution of the fusion programme. In fission research, participation rates of beneficiaries from NMS in successful projects is well above the Horizon 2020 average (17,93%).

#### 8.4.2. Distribution of funding

For the fission calls 2014-2015 and 2016-2017, beneficiaries in Member States have been awarded a total of €193,750,445.72 (see figure 5), with only Luxembourg and Malta not represented. Beneficiaries in associated countries (i.e. Switzerland and Ukraine, the latter associated only since 2016) have been awarded €4,764,620.53, and those in third countries €482,210.50. Third countries include Canada, Japan, Korea, Mexico, Norway, Russian Federation, Turkey, Ukraine (2014-2015 calls) and USA.

**Figure 5. Summary graphs (Euratom contribution and participation per country)**

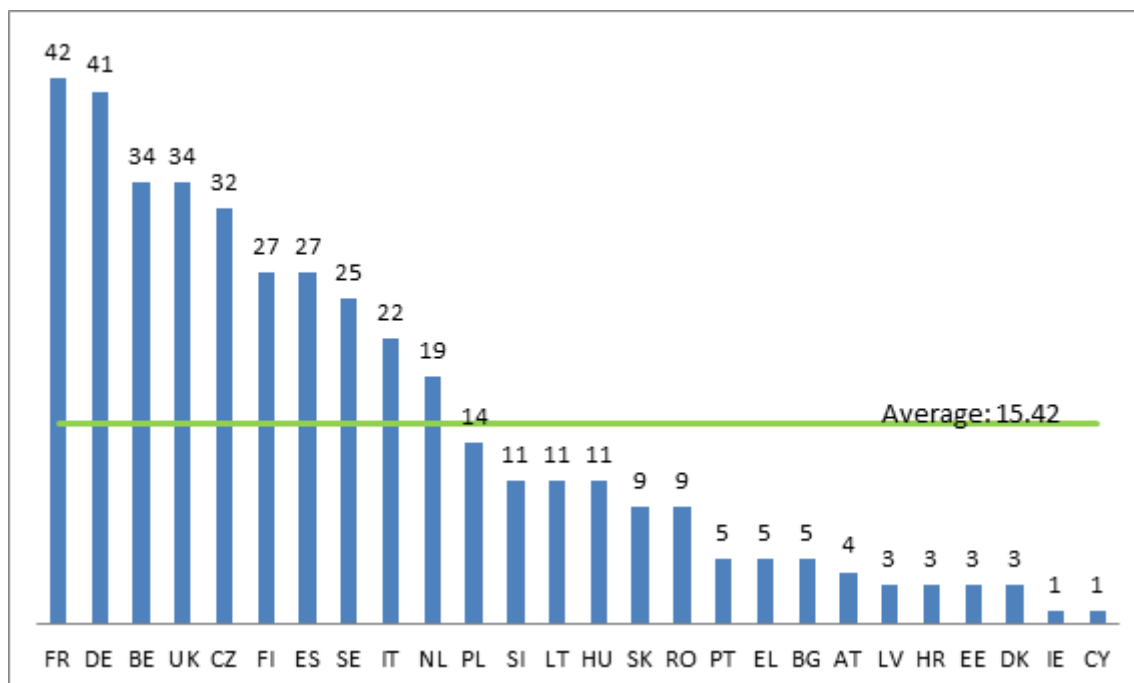


Source: European Commission

In Euratom FP7, the programme was quite concentrated in terms of geography, actors, resource distribution, etc. Beneficiaries from two Member States (Germany and France) participated in over three-quarters of all FP7 fission projects, while six Member States had participants in over half of all projects (Germany, France, Belgium, United Kingdom Spain and Sweden). French participants were by far the most prevalent in Euratom FP7 fission projects, followed by German, UK, Spanish and Italian. Together, these five Member States accounted for over 50% of all participation, and the corresponding EC contribution amounted to 62% of the overall allocated Euratom fission funding. A small group of 15 highly active organisations (who were participants in 25 or more projects) accounted for 29% of all participation and 49% of the total budget (i.e. EC plus participant contributions). Moreover, participating organisations from Germany, France, Belgium, United Kingdom Spain and Sweden were much more likely to cooperate with each other than with organisations from new Member States.

However, the trends from the first two years of Euratom Programme 2014-2018 provide some signs of increased involvement of Member States from Central and Eastern Europe as shown in figure 6.

**Figure 6: Number of fission projects in which Member States participated (2014 – 2017)**



*Source: European Commission*

## **9. COMPLEMENTARITY AND COHERENCE OF THE EURATOM PROGRAMME**

### **9.1. Complementarity of the Euratom programme with national (public and private) research priorities and activities**

The Euratom indirect actions in fission and radiation protection seek to accommodate for the needs of an extremely wide diversity of Member States, ranging from small Member States with no civil nuclear programme and almost no nuclear research activities, to large Member States meeting a large majority of their energy needs from nuclear power and on the international forefront of research. Even amongst the 14 Member States with civil nuclear programmes, the level of maturity of these programmes, the technology underlying their reactor fleet, the strategic orientations for the future development and the research needs and interests can differ significantly<sup>46</sup>.

Considering these boundary conditions, evaluation found that the Euratom programme is generally coherent with the fission research priorities and activities on the national level<sup>47</sup>:

- In the area of nuclear safety, Euratom priorities are well aligned with the needs of an ageing reactor fleet and addressing the inherent safety concerns arising from lifetime extension, as well as more generally improving knowledge of plant behaviour and performance and refining and developing new mitigation measures to respond to new risks as they appear (e.g. issues raised by the Fukushima accident). Most of the operating reactors were built in the 1970s and 1980s, and since the construction of reactors has slowed down in the last 30 years, the average age of the nuclear fleet has been continually growing and reached 32 years in 2016. The country with the oldest reactor fleet is the Netherlands (43 years), followed by Switzerland (41,4 years), Finland (37,8 years), Sweden (37,7 years), Belgium (36,4 years), Slovenia (35 years) and the United Kingdom (32,6 years). The average age of the reactor fleets in other Euratom Member States was equal to or less than the overall average<sup>48</sup>. The 2011 Fukushima accident revived public concern for the safety of NPPs and has led to national authorities strengthening their research programmes in this area, as well as the trend towards greater international cooperation in this field. The lessons learnt during the accident have also contributed significantly to shaping research priorities since 2011.
- Concerning research on advanced reactor systems, the Euratom programme has been focused on better understanding of safety implications arising from the development of Generation IV reactor concepts. Research priorities have been generally well focused on the most promising concepts being developed on the national level, in line with SNE-TP and ESNII strategy. They also generally complemented well national activities and provided small but useful support in the financially precarious early phases of concept definition and design.
- In the field of radiation protection, Euratom priorities have been as much about better structuring research as supporting the research itself. The Euratom programme has thus

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<sup>46</sup> For more details see Ernst & Young study on fission research

<sup>47</sup> *ibidem*, p.104 and later

<sup>48</sup> *Ibidem*, p.106 and later



been relevant to the need both to support research on specific topics and to assist Member States in achieving greater synergies between their national programmes.

## **9.2. External and internal coherence of the Euratom programme**

Euratom programme is coherent internally and with the other EU programmes and policies. Internal coherence between fission and fusion indirect actions is ensured by supporting projects addressing topics relevant for both fields. In the Euratom WP 2016-2017, the Commission included topics addressing cross-cutting issues between fission and fusion. The first topic (NFRP 13) concerned fission/fusion cross-cutting research in the area of multi-scale materials modelling, while the second (NFRP 14) aimed at cross-cutting support to improved knowledge on tritium management in fission and fusion facilities. Following the call two projects were launched in 2017, with total Euratom support of 8 million euro, addressing both topics (M4F – Multiscale modelling for fusion and fission materials, and TRANSAT - TRANSversal Actions for Tritium)<sup>49</sup>.

Synergies between direct and indirect actions are ensured by participation of JRC's institutes in consortia implementing indirect actions' projects, where they provide access to research infrastructures. In 2014-2015 call for proposals, JRC institutes are involved in 7 projects, mainly concerning safety research. Regarding 2016-2017 call for proposals, JRC is involved in 12 projects covering 7 work programme topics (out of 8) in nuclear safety and waste management. In addition JRC is involved in projects supporting education and training and materials research.

Regarding coherence of the Euratom programme with other EU programmes and policies, through the cooperative research, the Euratom indirect actions enable a Europe-wide approach to improving nuclear safety and radiation protection in all areas of application, which complements the implementation of the Euratom Directives on nuclear safety<sup>50</sup>, radioactive waste management<sup>51</sup> and basic safety standards<sup>52</sup>. Involvement in the research actions supported by the Euratom programme also facilitates participation of national and regional research stakeholders in other Union funding programmes, including the Structural Funds.

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<sup>49</sup> European Commission, results of the 2016-2017 call for proposals.

<sup>50</sup> Council Directive 2009/71/Euratom of 25 June 2009 and its revision 2014/87/Euratom, establishing a Community framework for the nuclear safety of nuclear installations.

<sup>51</sup> Council Directive (2011/70/Euratom) of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

<sup>52</sup> Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.

## 10. EU ADDED VALUE OF THE EURATOM PROGRAMME

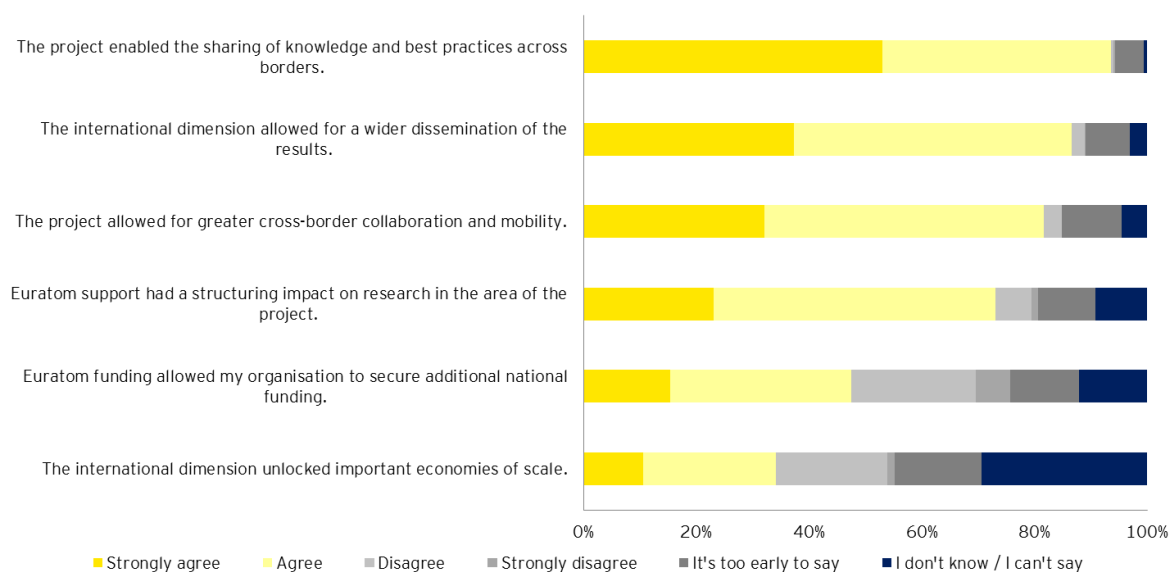
A key element of Euratom Programme added value is the ability to mobilise a wider pool of excellence, competencies and multi-disciplinarity in the nuclear research field than is possible at the level of individual Member States. This is demonstrated by a diverse portfolio of 23 projects launched in 2014-2017 addressing important aspects of nuclear safety (for example accident tolerant fuels, core monitoring techniques, assessment of structural integrity of NPP elements, ageing management etc.) as well as by the launch of the European Joint Programmes in fusion and radiation protection research. Another example is a joint exploitation of fusion research infrastructures, which rely on the collective endeavours of researchers and engineers from all across Europe (about 350 persons per year), supported by Euratom funding for mobility. This broad-based coordination throughout Europe of education and training, the use of research facilities and international cooperation is of particular benefit to smaller Member States, which can take advantage of the economies of scale afforded by the Europe-wide pooling effect – in fusion research this is exemplified by smaller laboratories that can specialise in scientific topics or subsystems for fusion research facilities in Europe and make important contributions while maintaining the visibility in the European consortium.

The 2016 survey carried out by Ernst&Young<sup>53</sup> aimed to understand the added value provided by Euratom research projects compared to research conducted on the national or bilateral levels. The respondents were presented with the opportunity to provide their opinion on several aspects of added value (see Figure 7). The main types of European added value underlined by the respondents are the improvement of sharing of knowledge and best practices across borders, the wider dissemination of results allowed by international dimension, the greater cross-border collaboration and mobility, and the contribution to the structuration of research in the area of the project. However the Euratom programme is not considered to have strong influence on financial aspects of the projects: only 34% of the respondents agree to say that the European project allow important economies of scale and a little under 50% that Euratom funding allow their organisation to secure additional national funding. Some respondents also underlined other types of added value. The European programme allows for the awareness of the European Commission on some important issues in nuclear research and enhance the creation of common vision of research challenges across European organisations. The European action is also considered as having an important role in ensuring training of the next generation of nuclear specialists through the collaboration between educational organisations and with nuclear companies.

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<sup>53</sup> Ernst & Young study, 2016.

**Figure 7: Main types of EU added value of the Euratom programme identified by the respondents**



N= 589

Source: Ernst&Young study

In the short term, Euratom fission research promotes added value by enhancing the safe and secure performance of providing electricity from nuclear energy, representing 27% of electricity in the EU and is the main low-carbon base load energy source in the European grid. Euratom research may also play a role in the security of energy supply at EU level, through dedicated R&D work on the diversification of fuel sources, notably regarding pressurised water reactors of Russian origin operating in the EU, and on the possible optimisation of the use of resources through further investigation of the safety and feasibility of closed fuel cycle options.

In the long term, both Euratom fission and fusion research can support the decarbonisation of the energy system by developing magnetic confinement fusion, including through support for ITER, and by improving safety aspects of new and innovative fission technologies. In the case of fusion energy in particular, it is clear that without past Euratom Programmes there would be no ITER, and certainly no ITER under construction in Europe. The Euratom Programme has therefore ensured that Europe is in a leading position in the next step in the quest for fusion energy – the demonstration in ITER of the feasibility of fusion energy at reactor scale – and the Euratom programme must now ensure that Europe can benefit from this leading position in the step that follows, namely the construction and operation of a DEMO facility to produce fusion electricity for the grid. Without such efforts, the investment in ITER would be jeopardised and the opportunity of fusion energy could be lost.

## 11. CONCLUSIONS

The interim evaluation concluded that the Euratom programme is relevant across the full scope of activities, including nuclear safety, security and safeguards, radioactive waste management, radiation protection and fusion energy. Action at EU level continues to be instrumental in addressing challenges faced by Member States in these areas. The Euratom programme helps ensuring that public financing is used in an optimal manner by avoiding unnecessary duplication while providing the required EU-added value and coordination. In this respect, the Euratom programme remains an important part of the European nuclear research landscape.

On the programme's efficiency and effectiveness, the CEG report on indirect research indicates some areas requiring action by the Commission and/or beneficiaries. This concerns in particular:

- the need to improve organisation and management of the European Joint Programmes in fusion and radiation protection research;
- the need to exploit synergies with other thematic areas of Horizon 2020 in order to address cross-cutting aspects such as health aspects of radiation.
- the need to seek synergies in application of some Horizon 2020 instruments in nuclear field such as Marie Curie Skłodowska Actions
- the need to review the impact of 100% reimbursement rate for direct costs of beneficiaries of indirect actions on the level and scope of research delivered by the Programme.

These will be addressed as appropriate over the coming months to optimise programme implementation during the 2019-2020 extension and better prepare for the post-2020 programme. Other recommendations, in particular on the long-term aspects of nuclear research or instruments that the Euratom programme shares with Horizon 2020, will be further analysed in the ex-ante impact assessment of the Euratom programme (post-2020) of the next multiannual financial framework.

**ANNEX 1: PROCEDURAL INFORMATION CONCERNING THE PROCESS TO PREPARE THE INTERIM EVALUATION OF INDIRECT ACTIONS OF THE EURATOM RESEARCH AND TRAINING PROGRAMME 2014-2018.**

**Lead DG:** Directorate General Research and Innovation (RTD)

**Agenda planning number:** 2015/RTD+/014 Interim evaluation

The requirement for the interim evaluation of Euratom programme derives from Article 22(1) of Regulation 1314/2013/Euratom establishing the programme. This stipulates that the Commission shall carry out, with the assistance of independent experts selected on the basis of a transparent process, an interim evaluation of the Euratom Programme on the achievements, at the level of results and progress towards impacts, of the objectives and continued relevance of all the measures, the efficiency and use of resources, the scope for further simplification, and European added value.

The interim evaluation of Euratom programme started in 2016 and has been guided by an Inter-Service Group (ISG). A roadmap summarising the design, purpose and scope of the interim evaluation, was published in May 2016<sup>54</sup>. An Inter-Service Group (ISG) gathering representatives of four Directorates-General (RTD, ENER, JRC, SG) of the Commission was set up in 2016.

The interim evaluation was coordinated by the Strategy Unit in Energy Directorate of the Commission's Directorate-General for Research & Innovation (DG RTD). This unit contracted studies and organised work of the independent Group of Experts.

The evaluation is based on a wide range of sources comprising internal assessments by Commission services as well as external expert group report, thematic evaluation studies, the results of the ex-post evaluation of the Euratom 7th Framework Programme (FP7).

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<sup>54</sup> [http://ec.europa.eu/smart-regulation/roadmaps/docs/2015\\_rtd\\_014\\_interim\\_evaluation\\_euratom\\_research\\_en.pdf](http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_rtd_014_interim_evaluation_euratom_research_en.pdf)

## ANNEX 2: STAKEHOLDER CONSULTATION

A public stakeholder consultation for the interim evaluation of Euratom research and training programme 2014-2018 was launched on 20 October 2016 and closed on 15 January 2017.

### Overview of respondents

The Commission received 323 answers from individuals and stakeholders in nuclear research in Europe, covering all areas of research and different activities (public research bodies, TSOs, umbrella organisations, NPP operators, waste management authorities etc.). 171 replies were submitted by individuals, and 152 replies came from organisations, mainly public research bodies (48) and TSOs (23), and SMEs (18).<sup>3</sup>/<sub>4</sub> of the respondents participated in the current or previous Euratom programme. 63% respondents indicated that they are 'end-users' of Euratom research.

Regarding all responses (323), they came mainly from France (18%), Italy (15%), Romania (11%), Germany (9%), Spain (7%), Belgium (6%), Finland (4%), Sweden (4%) and UK (4%).

Regarding the involvement in specific fields of nuclear research – 29% of respondents are involved in R&D on nuclear systems and safety, 14% in waste, 11% in fusion and Radiation Protection, 10% in education& training.

### Overview of answers to public consultation questions

1. The opinion of stakeholders regarding the current Euratom programme's relevance is quite positive: 80% of respondents agreed or strongly agreed that it is relevant. This opinion varies from field to field, showing the strongest support for E&T, waste and safety of existing reactors (answers 'agree' and 'strongly agree' were grouped together):

82%	Education and & Training activities
80%	Final disposal of nuclear waste
80%	Safety of existing nuclear systems
76%	Promoting innovation
75%	Safety of more advanced nuclear systems
75%	Providing research infrastructures of pan-European relevance
72%	Storage of nuclear waste
63%	Partitioning and transmutation of nuclear waste
63%	Low dose radiation research
63%	R&D for future fusion power plants
60%	Radiation protection aspects of medical applications
59%	Demonstration of feasibility of fusion as a power source
57%	Promoting industrial competitiveness
50%	Supply of radioisotopes

2. *In which areas is the current Euratom Programme making progress towards delivering its objectives (answers 'agree' and 'strongly agree' put together)?*

Nuclear safety	75%
Education & Training	71%
Waste	65%
Radiation protection	62%
Fusion	54%

3. *In which field Euratom Programme has played an adequate role in positioning Europe as a leader?* (answers 'agree' and 'strongly agree' put together)?

Fusion	56%
Radiation Protection	53%
Waste management	51%
Nuclear systems	45%

4. *Are the forms of funding provided through Euratom Programme relevant to the needs of stakeholders* (answers 'agree' and 'strongly agree' put together)?

Grants for research and innovation actions	70%
Grants for coordination and support actions	63%
Co-fund instrument for EJPs ( <i>EUrofusion and concert were not indicated</i> )	43%
Recognition prize (fusion prize was mentioned)	20%
Financial instruments (e.g. Innov Fin)	18%

5. The EU added value of the Euratom programme was rated high or very high by 72% of respondents.

6. Opinion on the EU added value of different aspects of the Euratom programme (answers 'agree' and 'strongly agree' put together):

Improving knowledge sharing and information dissemination	89%
Mobilising wider pool of high level multi-disciplinary competencies than is available at national level	85%
Undertaking programmes beyond the reach of individual Member States enabling reaching objectives that could no otherwise be achieved	82%
Having a leverage effect on public investment	50%
Achieving objectives at lower overall costs	49%
Having a leverage effect on private investment	30%

7. 65% of respondents agreed that the Euratom Program is coherent with other EU policies

8. 89% of respondents see consequences of discontinuing the Euratom Programme (10% don't know).

Negative impact on:	
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nuclear education & training	75%
research activities carried out by my organisation	72%
nuclear safety of more advanced nuclear systems in Europe	66%
nuclear safety of existing nuclear systems in Europe	65%
safe solutions for the final disposal of nuclear waste	65%
safe solutions for the storage of nuclear waste	61%
radiation protection in Europe	60%
EU position in fusion research	60%
Partitioning and transmutation of nuclear waste	58%
Development of radiation protection aspects of medical applications of radiation	52%
Development of the supply and use of radioisotopes	47%

9. Stakeholders were asked to rate different implementation aspects of the current Euratom Programme (answers 'good' and 'acceptable' put together):

Contents of the calls for proposals	69%
Clarity in the text presenting the calls for proposals	67%
Frequency of calls for proposals	65%
Time taken to evaluate and select proposals	65%
Procedures for project monitoring and reporting	62%
Balance between control and trust of beneficiaries	61%
Communication activities to attract applicants	61%
Time taken to establish contracts and launch projects	61%
Support of the EC services during grant preparation and implementation	58%
Time taken to issue payments to grant holders	58%
Balance between new research stakeholders and established organisations	57%
Quality of the feedback received by participants in the evaluation process	56%
Balance in calls between small and large projects	55%
Acceptance of the organisations usual accounting practices	54%
Actions helping to close the research and innovation gap in Europe, in particular concerning Member States which acceded the EU and Euratom in 2004 or later	49%

10. Regarding the question whether benefits of participating in the Euratom project exceed the costs of participation, 62% respondents indicated that benefits either strongly (33%) or slightly (29%) outweigh costs.
11. 76% respondents agreed that participation of research entities from non-EU countries brings added value to the Euratom Programme.



12. Very strong support for education and training under current programme - 94% respondent replied 'yes' to the question *'Should education and training activities be supported by Euratom Programme?'* And 36% replied that E&T is not sufficiently supported by the Programme
13. 34% of respondents answered yes to the question on whether new organisation of fusion R&D (roadmap implemented by EUROfusion) is an improvement. A smaller number of respondents were positive regarding transition to joint programming and appropriateness of the instrument (27% and 25% respectively). However for all three questions, the same percentage of respondents (59%) did not know answer.
14. An overwhelming majority of respondents (84%) agreed that the current Euratom Programme's objectives should be continued in the next Euratom Programme
15. When asked about specific fields of nuclear research respondents indicated (answers 'agree' and 'strongly agree' put together):

Supports training activities to maintain high level of nuclear competence in Europe	82%
Ensure availability of research infrastructures of pan-European relevance	82%
Promote innovation	81%
Support safety of more advanced nuclear systems	77%
Contribute to the development of safe solutions for final disposal of nuclear waste	73%
Support safety of existing nuclear systems	72%
Contribute to the development of safe solutions for the storage of nuclear waste	72%
Promote industrial competitiveness	65%
Contribute to the development of safe solutions for the partitioning and transmutation of nuclear waste	62%
Support low dose radiation research	61%
Support development of radiation protection aspects of the medical applications	59%
Support supply of radioisotopes	57%
Lay the foundations for future fusion power plants (e.g. by developing materials, technologies and conceptual design)	55%
Move towards demonstration of feasibility of fusion as a power source	54%

16. 58% of respondents were aware of the joint programming initiatives developed within fission. When asked to indicate in which fields Joint-Programming should be developed, the respondents indicated the following fields ('agree' and 'strongly agree' put together):

Nuclear waste management	57%
Nuclear safety of more advanced nuclear systems	56%
Materials of nuclear relevance	51%
Nuclear safety of existing nuclear systems	49%

17. Regarding support for E&T, respondents were asked which fields are important ('crucial'). While many people indicated so, there were also many answers (20%-30%) indicating that this activity is important but it should be better addressed at MS or industrial level.

Nuclear safety of more advanced nuclear systems	56%
Waste management	50%
Nuclear fusion	48%
Radiation protection	47%
Nuclear security	45%
Nuclear safety of existing nuclear systems	44%

18. Mobility of researchers is another point of concern for respondents – while 34% agreed that Euratom provides sufficient support, 29% disagreed at the same time. This is probably why 63% of respondents was in favour of Euratom offering grants for access to nuclear infrastructure of the JRC sites.

### ANNEX 3: SUMMARY OF SOFT INNOVATION PRIZES AWARDED BY THE EURATOM PROGRAMME (2014-2016)

#### SOFT Innovation Prize 2016

<b>Proposal number:</b>	731318
<b>Acronym:</b>	CroCo
<b>Funding scheme:</b>	Recognition prize
<b>Proposal title:</b>	A new type of high temperature superconducting cable
<b>Total costs:</b>	50.000 €

At Karlsruhe Institute of Technology (KIT) and, in partnership with the Swiss Plasma Center (SPC) of Ecole Polytechnique Fédérale de Lausanne, a novel and innovative type of high temperature superconducting cable based on REBCO material has been developed. This innovation is the scope of this application.

High Temperature high current superconductor cables are future keys to manufacture large high field magnets, because they provide efficiency and low inductance of the magnets, minimizing the high voltage requirements in case of quench. However, the established technology of low temperature superconductors NbTi and Nb<sub>3</sub>Sn is at the limit for the ITER magnets and an increase of operating temperature or a distinct increase of field is not possible.

High temperature superconductors (HTS) REBCO material allows higher currents at higher magnetic fields and/or temperatures, but the assembling into high current cables (e.g. 68 kA for the ITER TF coil) is challenging, due to the extreme aspect ratio of the thin REBCO tape. SPC has made a proposal to use round stacked conductors as basic strands for a Rutherford cable and demonstrated 60kA @ 5 K and 12 T. KIT recognized the exceptional potential of the round twisted stack concept of SPC and optimized current density, facilitated the joint formation and demonstrated a simple fabrication technology of long-length units named "CroCos". These CroCos can be used as base elements in high field magnet application and offer at the same time a large potential for power applications, transferring fusion know-how to industrial applications, e.g. low loss DC power transmission cables operated at 100 kA and cooled with liquid nitrogen.

<b>Proposal number:</b>	731446
<b>Acronym:</b>	TRI2H2
<b>Funding scheme:</b>	Recognition prize
<b>Proposal title:</b>	New membrane technology to produce ultra-pure hydrogen
<b>Total costs:</b>	25.000 €

At ENEA, Frascati and, in partnership with CEA, Cadarache (SPC), a novel and innovative type of membrane for hydrogen purification has been developed. This innovation is the scope of this application.

Palladium-based membranes have been studied for separating hydrogen isotopes in the fusion fuel cycle. ENEA and CEA designed and tested membrane reactors made of dense Pd-Ag

tubes in a process developed for the recovery of tritium from JET soft housekeeping waste. These Pd-membranes exhibit infinite selectivity to the hydrogen isotopes and, therefore, can operate the detritiation processes with high efficiency. The tests carried out at Cadarache laboratories verified the effectiveness of the studied process for both detritiating the waste and recovering tritium in form of HT. The same Pd-membrane reactors have been tested for producing ultra-pure hydrogen via reforming of hydrocarbons, alcohols and biomass. In fact, fixed bed membrane reactors consisting of Pd-Ag membrane tubes filled with catalyst produce hydrogen with hydrogen yields higher than those of traditional reactors. Thanks to the proper mechanical design developed in the fusion fuel cycle applications, the Pd-membrane reactors exhibit good durability and reliability. Experiments demonstrated the effectiveness of these devices for recovering pure hydrogen from biomass. Particularly, Olive Mill Wastewater (OMW), that represents a major environmental concern because of its high pollution potential, has been successfully valorized for producing hydrogen and syngas by means of tubular Pd-membrane reactors.

<b>Proposal number:</b>	731435
<b>Acronym:</b>	VORTEX
<b>Funding scheme:</b>	Recognition prize
<b>Proposal title:</b>	New virtual reality software technology to improve radioprotection
<b>Total costs:</b>	12.500 €

At UKAEA, Culham, a novel and innovative software technology making use of virtual reality to improve radioprotection has been developed. This innovation is the scope of this application.

This innovation called VORTEX (Virtual Operator RadiaTion EXposure) combines virtual reality with radiation transport calculations in order to accurately determine the total dose to operatives and equipment during maintenance tasks in radiation environments. Used in a fission or fusion plant environment, VORTEX will enable the detailed planning of such tasks with a view to minimizing the exposure of the workforce.

#### SOFT prizes 2014

<b>Proposal number:</b>	643929
<b>Acronym:</b>	KALPUREX
<b>Funding scheme:</b>	Recognition prize
<b>Proposal title:</b>	A new process for continuous and non-cryogenic fusion exhaust gas pumping with a separation function for direct internal recycling
<b>Total costs:</b>	15.000 €

At Karlsruhe Institute of Technology (KIT), a novel and innovative fusion fuel cycle concept for DEMO and future fusion power plants has been developed. This innovation is the scope of

this application. It is based on a continuous and non-cryogenic but still fully tritium compatible process to pump the exhaust gas of the reactor. It further includes a direct internal recycling path for separation of pure hydrogen from the exhaust gas and leading it directly to the fuelling systems, in a short-cut around the tritium plant. By these measures, the tritium inventories are decreased, the cycle times are minimized and the tritium plant size is reduced. It therefore solves a potential showstopper and helps to make fusion energy more cost-attractive. KALPUREX (Karlsruhe liquid metal based pumping process for fusion reactor exhaust gases) is the process to implement this new and innovative concept. It is based on the use of a metal foil pump for separation and hydrogen recycling, of a mercury diffusion pump for primary pumping and of a mercury liquid ring pump for rough pumping. All three pump technologies had to be further developed with novel design solutions to make them suitable for fusion applications.

#### **ANNEX 4: AN OVERVIEW OF IMPORTANT SCIENTIFIC RESULTS IN FUSION RESEARCH (HIGHLIGHTS ON THE BASIS OF 2016 ANNUAL REPORT OF EUROFUSION)**

In the area of ITER relevant physics and support for future operation of the device several advances were made. For example, milestones set up to increase the confidence in JET performance being on track to reach the levels required for a successful Deuterium-Tritium (DT) campaign in 2019/20 were rapidly met when high power Neutral Beam heating became available from mid-September 2016. These milestones had been formulated by the independent EUROfusion Science & Technology Advisory Committee (STAC) and it was crucial that they were met. A future JET DT campaign should yield invaluable results and experience in support of ITER (the DT fuel species mix will be used by ITER in its full performance phase). An important factor for enhancing the performance of JET has been to overcome the lower energy confinement found experimentally with the ITER Like Wall (ILW). Significant progress was made in improving the JET confinement during 2016, and the underlying reasons for the reduced energy confinement in the edge plasma region with the ILW are becoming clearer. Both experiments on JET and on ASDEX-Upgrade have made significant contributions in this respect (ASDEX Upgrade is also operating with a metallic wall). To put JET's role for risk mitigation into context for ITER, the ILW has now been operated for 6 years and if the same understanding on operating with a metal wall were to have been obtained from ITER experiments it would likely have taken much longer time (the number of experiments it will be possible to carry out on ITER per day are much fewer than what is achieved on JET) and been vastly more expensive (one year of operation of ITER will cost Europe ~85M€).

Another important result, with potential implications for ITER, was discovered in a special Hydrogen campaign at JET (normally JET is operated with Deuterium plasmas). It was found that operation of hydrogen plasmas with only a small amount of Helium mixed in (~10%) required significantly less auxiliary heating power for the discharge to enter into to a so called high performance mode (H-mode). The standard operating scenario for ITER discharges should be H-mode and one would like to explore this confinement mode as early as possible. Unfortunately, with a single ion species the power required for entering into H-mode is about inversely proportional to the mass of the of the ion species. This poses a problem because in the initial (non-nuclear) phase of ITER the plan is to operate hydrogen plasmas. Because hydrogen has the lowest mass and the amount of auxiliary heating power available in the non-nuclear phase will be limited it would be very challenging to enter into H-mode in early ITER operation (one might have to resort to operating a very low magnetic field or in Helium plasmas, none of which is unproblematic). However, if the JET result extrapolates to ITER it would significantly ease the difficulty of operating early with H-modes.

Progress with important implications for ITER was made not only in terms of plasma physics. Just to mention an example, the dust generated by the JET ILW has been studied very carefully. Dust is a particular concern for ITER because of the tritium that can be lodged in it. Tritiated dust poses a number of safety hazards and could degrade e.g. in vessel diagnostics. The good news is that the dust generated by the ILW has been found to be two orders of magnitude below that of the previous carbon wall. This combined with analysis of the sources of dust generation with the ILW provides highly relevant information for ITER.

Of course the EU fusion roadmap is not only concerned with tokamaks like ITER and JET, but also with an alternative configuration: the stellarator. It can be viewed as a backup strategy to the tokamak or as a possible alternative for a second generation of fusion power

plant. Mission 8 of the roadmap is dedicated to the stellarator and when W7-X in Greifswald, Germany, came into operation a significant milestone was reached. The commissioning and experimental campaign in 2016 demonstrated the accuracy of the magnetic field lines and higher than expected performance. In fact the experimental campaign resulted in significantly more results than had been anticipated and was a great success.

An increasingly important aspect of fusion research is fusion technology and a number of advances were made in 2017. One of the perhaps most significant ones was a breakthrough in the development of High Temperature Super Conductor (HTS). The programme conducted in the framework of EUROfusion developed a novel fabrication route to embed several HTS tapes into a round conductor called “CROCO”. The development was entered into the 2016 SOFT recognition prize and won 1st place due to its novelty and wide range of applications beyond fusion. In fusion research it opens up the possibility of having very high field superconducting magnets which may have an impact on the size and cost of a fusion reactor.