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PROPOSAL

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To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2018) 307 final - Part 3/3
Subject:	COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Proposals for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing the specific programme implementing Horizon Europe – the Framework Programme for Research and Innovation COUNCIL REGULATION establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025 complementing Horizon Europe – the Framework Programme for Research and Innovation

Delegations will find attached document SWD(2018) 307 final - Part 3/3.

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PART 3/3

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposals for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination

DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing the specific programme implementing Horizon Europe – the Framework Programme for Research and Innovation

COUNCIL REGULATION establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025 complementing Horizon Europe – the Framework Programme for Research and Innovation

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Annex: Impact assessment of the Euratom Research and Training Programme 2021-2025

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Glossary

Term or acronym	*Meaning or definition*
ALLIANCE	Research platform to coordinate and promote European research on radioecology (http://www.er-alliance.org/)
Applicant	Legal entity submitting an application for a call for proposals
Application	The act of a legal entity becoming involved in a proposal. A single applicant may submit applications for one or more proposals
Associated country	Non-EU country that is party to an association agreement with the Euratom research and training programme. It participates in the programme under the same conditions as EU Member States. Two countries are associated to Euratom programme: Switzerland (since 1979) and Ukraine (since 2016)
CBRN	Chemical, biological, radiological and nuclear
CSA	Coordination and Support Action
DEMO **DEMO CDA** **DEMO EDA**	Demonstration power plant that will generate fusion electricity Conceptual design activity for DEMO Engineering design activity for DEMO
DONES	DEMO-oriented neutron source
Deuterium, tritium	In nature, hydrogen comes in three forms, called isotopes. Deuterium (heavy hydrogen) is twice and tritium (super heavy hydrogen) is three times heavier than common hydrogen. First-generation fusion power plants burn the hydrogen isotopes deuterium and tritium as fuel
DG RTD	European Commission's Directorate-General for Research and Innovation
Divertor	Part of a tokamak where the power exhaust takes place
EAV	European added value
ECVET	The European Credit system for Vocational Education and Training
EESC	European Economic and Social Committee
EFDA	European Fusion Development Agreement
EFSI	European Fund for Strategic Investments
EJP	European Joint Programme
ENEN	European Nuclear Education Network
ENSREG	European Nuclear Safety Regulators Group
ERC	European Research Council
ESIF	European Structural Investment Funds
ESFRI	European Strategy Forum on Research Infrastructures
ESNII	European Sustainable Nuclear Industrial Initiative
EUROfusion	The EUROfusion consortium, launched in 2014, carries out research funded jointly by Euratom and the Member States. EUROfusion implements fusion research in line with the European roadmap to fusion electricity

F4E	Joint undertaking for the ITER research facility and the development of fusion energy in Barcelona, Spain
FIIF	Fusion Industry Innovation Forum
FLCM	Full lifecycle cost management
FP	Horizon Europe Framework Programme for Research and Innovation
Fusion energy	Energy released by the fusion process, a process that merges together or ’fuses’ the cores of atoms and that powers the sun and stars in our solar system
Generation-II/-III	Current generations of nuclear power plants
High-power deuterium-tritium (D-T) campaign	A type of fusion experiment in which the highest amount of fusion energy is released and the best fusion performance obtained
High-quality Proposal	A proposal that scores above set evaluation threshold, making it eligible for funding
HLW	High-level (radioactive) waste
IA	Impact assessment; innovation action
JRC	Joint Research Centre, a Directorate-General of the European Commission
KPI	Key performance indicator for measuring the performance and impacts of the Euratom programme
Magnetic confinement fusion	A fusion technology in which an extremely hot hydrogen gas, a plasma, is held together or ‘confined’ with strong magnets
MELODI	Multidisciplinary European Low Dose Initiative (http://www.melodi-online.eu/)
MFF	Multiannual Financial Framework
MSCA	Marie Skłodowska-Curie Action
NDAP	Nuclear decommissioning assistance programme
Newcomer	A participant in the Euratom programme who was not involved in Euratom FP7 Project
NMS	New EU Member States (since 2004)
NPP	Nuclear power plant
Participant	Any legal entity carrying out an action activity or part of an action under the 2014-2018 Euratom programme
Participation	A legal entity’s involvement of in a project. A single participant may be involved in multiple projects
Plasma	Plasma is a state of matter alongside solid, liquid and gas. Our sun and stars are made of plasma. Plasma is produced in fusion experiments
Power (energy) exhaust	A technology to control the power (energy) outflow of a fusion plasma
Project	Successful proposals for which a grant agreement is concluded

R&I	Research and Innovation
RIA	Research and Innovation Action
SME	Small or medium-sized enterprise
SRA	Strategic research agenda
STC	Scientific and Technical Committee
Success rate	The number of proposals that are retained for funding over the number of eligible proposals
TFEU	Treaty on the Functioning of the European Union
Third country	A country that is not a Member State of the EU. For the purposes of this document, the term 'third country' does not include associated countries (see above)
Time to grant	The time that elapses between the closing date for the call and the signing of the grant agreement, which marks the official start of the project
Tokamak	A torus-shaped device which uses a strong magnetic field to confine a plasm. The main device used by fusion researchers for fusion experiments
TRL	Technology Readiness Level. These levels measure the maturity level of particular technologies. The measurement system provides a common understanding of technology status and covers the entire innovation chain: TRL 1 – basic principles observed; TRL 2 – technology concept formulated; TRL 3 – experimental proof of concept provided; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment; TRL 6 – technology demonstrated in relevant environment; TRL 7 – system prototype demonstrated in operational environment; TRL 8 – system complete and qualified; TRL 9 – actual system proven in operational environment

1. INTRODUCTION: POLITICAL AND LEGAL CONTEXT

This impact assessment accompanies the Commission's proposal for the Euratom research and training programme for 2021-2025 (Euratom programme). In turn, the programme complements the Horizon Europe Framework Programme for Research and Innovation (FP) in the area of nuclear research and training.

On 2 May 2018, the European Commission adopted its proposals for a new Multiannual Financial Framework (MFF) for 2021-2027. Under these proposals, the Euratom programmes will have a budget of EUR 2400 million over this period[1]. This impact assessment report reflects the decisions of the MFF proposals and focuses on the changes and policy choices, which are specific to this instrument.

The Euratom programme is one of the spending programmes that will implement the Commission's vision for the period beyond 2020. Bearing in mind the lessons learned and progress achieved so far, the impact assessment will look at whether the existing programme should continue with its present form or undergo changes to its scope and structure.

1.1. Context

Research and innovation (R&I) programmes are crucial for implementing the Commission's vision as set out in the proposal for the next MFF. The Commission's reflection paper on the EU's finances[2] and the its Communication on the future MFF[3] both highlight the significant role and added value of research programmes supported from the EU budget. R&I programmes are key in improving people's well-being, creating growth and jobs and finding solutions to a range of challenges.

Nuclear and radiation technologies continue to play an important role in the lives of all Europeans, in that they influence energy and climate change policies, security of supply, energy research and the use of radiation and radionuclides in non-power (medical, industrial, etc.) applications. The secure and safe use of these technologies remains paramount. R&I programmes play a key role in maintaining and using the highest standards of safety, security, waste management and non-proliferation and in retaining Europe's leadership in the nuclear domain so as not to increase energy and technology dependence — this being one aim of the Energy Union[4].

The Euratom programme is an EU-funded thematic research and training programme operating in scientific and technical areas covered by the Euratom Treaty[5]. The Council adopts the programme by unanimous agreement based on Article 7 of the Euratom Treaty.

The funded research focuses on nuclear safety, safeguards and security, radioactive waste management, radiation protection and fusion energy. The promotion of nuclear research remains a key provision of the Euratom Treaty (Article 4), which derogates from the

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1 In line with Article 7 of Euratom Treaty the proposal covers 5 years (2021-25). Years 2026 and 2027 will be covered by a separate proposal.

2 https://ec.europa.eu/commission/sites/beta-political/files/reflection-paper-eu-finances_en.pdf.

3 COM(2018) 98.

4 See Energy Union Package, COM(2015) 80.

5 Annex 1 to the Euratom Treaty.

general provisions for research under the Treaty on the Functioning of the European Union (TFUE).

As a result, EU R&I programmes (currently Horizon 2020) do not fund topics covered by the Euratom Treaty; only the Euratom programme supports research at European level in this field. Until today, nuclear researchers were not eligible for funding from bottom-up EU programmes such as the European Research Council (ERC) or Marie Skłodowska-Curie Actions (MSCAs).

The current Euratom programme will end on 31 December 2018[6]. On 1 December 2017 the Commission submitted to the Council a proposal[7] to extend this programme until 2020 to bring it into line with the current seven-year MFF, running from 2014 to 2020.

Other MFF-related proposals are closely linked to the Euratom programme and more should be done to exploit the synergies between them (see Table 1).

Table 1 — Synergies with other MFF-related proposals

Proposed programmes for the new MFF	Links to Euratom programme 2021-2025
Horizon Europe Framework Programme for Research and Innovation	The Euratom programme complements the Horizon Europe Framework Programme's research activities and shares the same rules for participation. The main features of the delivery mechanism for the Euratom programme (calls, funding model) will also be shared with the Framework Programme. Implementing the specific objectives of the future Euratom programme will require cross-cutting actions with the Framework Programme to tackle today's societal challenges. There will be access for nuclear researchers to horizontal programmes, such as MSCAs (which will support the Euratom programme's education and training goals).
Union Funds under shared management	The future Union Funds under shared management (in particular the ERDF, ESF+ and EAFRD) will provide a large share of the EU funds for R&I. Holders of Seal of Excellence awards from directly managed Union programme should be eligible for this funding.
ITER	ITER will be a key research infrastructure for the Euratom programme's implementation of the European roadmap to fusion electricity, starting in 2025. The Euratom research programme (implemented by DG RTD) will be carried out in full complementarity and coordination with the activities of DG ENER (responsible for ITER) in support to the construction of ITER and preparation of operation and Broader Approach activities.
Nuclear Decommissioning Assistance Programmes (NDAP) and JRC decommissioning	The NDAP and JRC programmes should provide feedback from decommissioning activities as input for future research in this field. The Euratom programme will fund research activities supporting the development and evaluation of technologies for the decommissioning and environmental remediation of nuclear facilities. The programme will also support the sharing of best practices and knowledge on decommissioning.

1.2. Scope of impact assessment

This impact assessment focuses on the outcome of the Euratom programme's interim evaluation and stakeholder consultation. This will help determine any changes needed in the programme's scope, aims and delivery method, taking into account cross-cutting objectives under the new MFF (flexibility, focus on performance, coherence and

6 Pursuant to Article 7 of the Euratom Treaty, Euratom research and training programmes can be adopted for five years.

7 COM(2017) 698.

synergies, simplification). It also meets the requirements of the Financial Regulation as regards preparing an ex-ante evaluation for the proposed Council Regulation establishing the Euratom Research and Training Programme 2021-2025.

However, it does not cover the rules for participation. As is currently the case with Horizon 2020 and the Euratom programme, these will be shared with the Horizon Europe Framework Programme for Research and Innovation (see the IA for the Horizon Europe). Neither does it cover ITER[8], which is an essential element of the European fusion roadmap[9]. The impact assessment concerning the financing and the activities of the Fusion for Energy Joint Undertaking (F4E) – the EU's implementing agency for the ITER construction and Broader Approach activities, among others – is provided in a separate document.

The impact assessment for the Horizon Europe Framework Programme provides details of the related structural and policy issues affecting European R&I in general. Many of these issues are equally relevant for the Euratom programme, though the particular features of the nuclear research sector should be borne in mind. These include the need for large and expensive research infrastructures and high levels of public funding in some key areas (e.g. fission and fusion research or advanced materials).

The programme centres specifically on: safety at existing (fission) nuclear power plants; the lower proportion of SMEs in some areas because of the cost of research and related infrastructures; significant involvement from national public bodies/agencies; a sharper focus on education and training; and, last but not least, the fundamental importance of international cooperation. Where the impact assessment for the Horizon Europe is considered inadequate or inapplicable for the specific case of Euratom research, the issues are addressed in this document.

1.3. Lessons learned from previous programmes

Evaluations of successive Euratom programmes have shown how European support is vital for nuclear research to continuously enhance the safety and security of nuclear technologies.

The key findings from the interim evaluation of the 2014-2018 Euratom programme are set out below[10].

a) *Continue supporting nuclear research focused on nuclear safety, safeguards, security, waste management, radiation protection and development of fusion*

The interim evaluation concluded that the Euratom programme is highly relevant across all activities, including nuclear safety, security and safeguards, radioactive waste management, radiation protection and fusion energy. Actions at European level in nuclear research continue to be instrumental in maintaining and using the highest

[8] ITER, meaning 'the way' in Latin, is the fusion research facility under construction in southern France as part of a worldwide collaboration.

[9] Fusion electricity – a roadmap to the realisation of fusion energy (https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/)

[10] COM(2017) 697.

standards of safety, security, waste management and non-proliferation, and in retaining Europe’s leadership in the nuclear domain[11].

b) *Further improve, together with beneficiaries, the organisation and management of the European Joint Programmes in the nuclear field.*

The interim evaluation of the Euratom programme 2014-2018 found that the introduction of the European Joint Programme (EJP) Cofund action had been a success. The EJP instrument is designed to support coordinated national R&I programmes. It aims at attracting and pooling a critical mass of national resources for the Euratom programme’s objectives and at achieving significant economies of scale by gathering related Euratom resources around a joint effort.

The independent group of experts running the evaluation made specific recommendations to improve the organisation and management of the EJPs in the nuclear field. These recommendations, while not questioning the basic structure or approach, require further refinements and changes to the EJP for it to remain effective going into the next programming period (2021-2025 and beyond). For more details on these recommendations and how the Commission’s services addressed them, see section 4.1 (delivery methods for the funding under the future programme).

c) *Continue and reinforce the Euratom education and training actions for developing competencies in the nuclear field which underpin all aspects of nuclear safety, security and radiation protection*

The interim evaluation underlined the importance of developing comprehensive action for maintaining and developing nuclear skills in Europe, while also finding synergies with the Framework Programme’s actions supporting education and training.

Maintaining competencies in safety, radiation protection and safeguards in nuclear regulatory authorities and the nuclear industry will be one of the critical challenges to effective regulation of nuclear power, nuclear science and ionising radiation technology applications in the coming decades. The challenge arises from the age profile of staff in the regulatory bodies — natural wastage (mostly due to retirement) over the next decades could see the present nuclear safety knowledge base disappear — and from a decline in the numbers of nuclear science and engineering students.

In this context, the interim evaluation concluded that some specific changes should be implemented to give the Euratom programme greater impact in this area. The Euratom indirect actions in education and training should have more specific and measurable objectives. On the other hand, the Joint Research Centre (JRC) should enhance access to its research infrastructures and reinforce its education and training activities — in particular, hands-on practical training and work experience. The independent expert group proposed that students and researchers in the nuclear field should be eligible to take part in MSCAs, which provide mobility grants, and foster career development. In fusion research, the EUROfusion consortium should put more emphasis on training nuclear engineers and technologists for the next phase — the design of a demonstration fusion power plant.

d) *Further exploit synergies between Euratom programme and other thematic areas of the Framework Programme to address cross-cutting aspects such as the medical*

[11] See Energy Union Package, COM(2015) 80.

applications of radiation, climate change, security and emergency preparedness and the contribution of nuclear science

The interim evaluation concluded that the Commission should aim at developing joint research actions on the radiation protection aspects of medical practices, as well as innovative nuclear medicines. Euratom should not develop such research alone, but do so jointly with the health part of the Horizon Europe. The Commission should also seek other synergies between nuclear and non-nuclear activities and nuclear science applications such as security of energy supply, public involvement in decision-making, security of supply of medical radioisotopes and nuclear sciences applications in support of the sustainable development goals.

e) *Further exploit synergies between direct and indirect actions of the Euratom programme*

The interim evaluation recommended that the Commission should implement coherent programming of the direct and indirect actions of the Euratom programme, with well-defined governance and decision-making processes. This will help achieve maximum synergy between the indirect and direct actions, and enable the programme to operate with maximum efficiency and the most effective results possible. One scenario could be that JRC might cease to participate in Euratom calls for proposals if a mechanism on the role and participation of JRC in the indirect actions funded by Euratom is established. Instead, when proposing research topics a process should be established to allow the JRC to contribute with its direct actions to the projects with its competences and expertise including an open access to its research infrastructures to all interested consortia.

1.4. Feedback from stakeholders

To gather information on the programme's performance and on the research challenges to be addressed in the future, in 2017 and 2018 the Commission held two consultations, a roundtable on decommissioning, and a workshop with stakeholders to explore their specific needs. It also received an opinion from the Euratom Scientific and Technical Committee (STC)[12].

The input given was consistent with the findings from the Euratom programme's interim evaluation and provides additional insights into issues of importance to nuclear research in Europe. The Commission used this important feedback in drafting this impact assessment and the proposal for the Euratom programme, in particular on the scope and delivery mechanism.

The 2018 consultation, to which the Commission received 353 responses, was addressed specifically to research stakeholders such as technology platforms, nuclear regulators, public research bodies, universities and technical support organisations. The main purpose of the consultation was to seek stakeholders' views on the issues that the Euratom programme 2021-2025 should address, the programme's support for access to infrastructures, education and training, and the integration of direct and indirect actions.

The 2017 consultation[13] was an open public consultation to evaluate the Euratom programme from 2014 to2018 and prepare for its extension to 2019 and 2020. The

[12] STC opinion on future Euratom research and training programmes, February 2017.
[13] For details on the 2017 public consultation see SWD(2017) 427.

Commission received 323 responses from individuals, research stakeholders and public authorities.

Table 2 provides an overview of the key messages from both consultations. For an overview of all replies from the 2018 consultation, including all position papers, see Annex 2.

Table 2 — Key messages from 2017 and 2018 consultations	
Scope of programme	- The programme should continue to cover current research areas (nuclear safety, security, radioactive waste management, radiation protection, fusion energy) but funding should be more focused to maximise impacts. - Research on ionising radiation and nuclear science (medical applications) should be supported by joint initiatives funded by Euratom and other programmes (for example, the health part of the Horizon Europe) or by research programmes other than Euratom. - The Euratom programme should play a larger role in decommissioning, although stakeholders consider that Programme should be focused mainly on specific issues in decommissioning, such as skills development and exchange of best practices.
Instruments to be used	The future programme should continue to use current instruments to support research (research and innovation actions, innovation actions, coordination and support actions, European Joint Programmes).
European added value	European added value has come in the form of: funding for research, access to knowledge and/or nuclear facilities not available or difficult to acquire at national level, skills development, the establishment of research networks, and acquiring a critical mass of resources.
Access to R&I infrastructures	The Euratom programme should support access to relevant research infrastructures in Europe, including the JRC infrastructures.
Role of direct actions of the Euratom programme (carried out by the Joint Research Centre)	- The JRC should provide independent scientific advice in Europe and support for EU policies. - It should carry out research complementing national initiatives and develop a knowledge management centre for Euratom research. - Preferably, it should not compete in Euratom calls for proposals, but instead provide in-kind contribution in research to Euratom indirect actions. It should also play a coordinating role in knowledge management for the research results obtained.
Support for education, training, mobility	The programme should shift more resources towards addressing basic needs in education and training and mobility. Researchers would benefit from individual support when it comes to fellowships for PhD and postdoc researchers. The programme should support networking and exchanges among researchers and access to infrastructures, including the Commission's research infrastructures.
Fusion energy research	The creation of EUROfusion is an improvement (according to more than two-thirds of stakeholders). Researchers should enjoy greater mobility.

In February 2018 the Commission organised a workshop for research stakeholders and representatives of Member States on the following theme: 'Euratom Nuclear Fission Research and Training — What are the new specific needs?' Table 3 below gives the key messages from the workshop[14].

[14] Workshop held on 21 February 2018 in Brussels.

Table 3 — Key messages from 2018 workshop	
Research infrastructures in nuclear field	Euratom support for accessing research infrastructures, including the JRC, should be developed taking into account the different needs of stakeholders (open access for academia, commercial access for industry) and the range of access conditions (type of infrastructure, duration of access, size of team, technical support needs, etc.). Funding researchers' travelling, lodging and living costs should be also considered. Mapping research infrastructures and prioritising them for Euratom support should follow once open access is guaranteed.
Nuclear education and training at EU level	Education and training in nuclear issues is closely linked to research infrastructures in this field. The issues are of a complexity that requires hands-on training to pass on know-how efficiently. As both the infrastructures and the workforce are ageing, it is important to maintain the European capabilities necessary for anticipating future nuclear safety challenges in operating the current nuclear fleet. At the same time, it is important to make nuclear education more attractive to a younger generation by laying the foundations for research into forward-looking technologies, and also to be open to countries where major development is ongoing. One of the key challenges is trans-European knowledge-sharing and transfer across different fields and generations.
Nuclear science and ionising radiation technology applications	Nuclear science and ionising radiation technology applications, which go beyond the classical power sector, are increasingly important for medical, industrial and space applications, for instance. Nuclear medicine depends on the development of new pharmaceuticals and the transition from research to clinical practice, security of supply of radioisotopes and is governed by radiation protection and pharmaceutical legislation. The EU is a leader in this field and there is strong societal interest to further develop it. For this reason, maintaining European nuclear infrastructures and knowledge is critical for the development and sustainability of these applications, and the regulatory framework and research funding should be properly coordinated in the EU.
Innovation in nuclear research	In nuclear safety, it is vital to maintain know-how about the existing nuclear fleet and anticipate future nuclear safety challenges needs to be ensured. A bridge between research activities in the medical and non-medical sectors will be beneficial for both. The early involvement of the regulators is needed to facilitate the deployment of innovative technologies.

The 2017 opinion from the STC, the advisory committee appointed by the Council, on future Euratom research and training programmes included the following remarks (excerpt):

- the urgent need for a coordinated and coherent approach to infrastructure investment. This will ensure that the EU gives value for money; that it provides for appropriate leverage both between and within the 'direct actions' and 'indirect actions' components of the Euratom research and training programme; and that it delivers enduring capacity and capability in facilities that underpin nuclear technology and that are vital for Member States in all related fields, including those essential for medicine and radiation protection, security and safeguards;

- The need for Europe to continue maintaining skills and knowledge in advanced nuclear systems to be able to fulfil its potential and occupy its rightful position in the evolving international initiatives in this field ensuring the highest standards of safety, security, waste management and non-proliferation are achieved and maintained globally;

- the need to continue the R&D efforts on waste management and geological disposal in the existing reactor fleet;

- the significant cross-cutting benefits that can be realised between fission and fusion energy research programmes as the latter evolves from one focused on basic plasma physics to one focused more on technology and nuclear-related aspects;

- the need to pursue efforts on radiation protection research where the focus remains on low-dose risk, which has important implications for EU citizens in view of the growing exposure from medical diagnostic and therapeutic practices, and in which research actions should therefore be co-funded by the Horizon 2020 health programme. This would free up limited Euratom funding for nuclear technology priorities, such as the efficient production of radioisotopes for medical purposes and biological research;

- the need for the European programmes to include R&D in dismantling and decommissioning activities, so as to maintain the capacity and capability to undertake them in the future. The report recognises that there is presently no Euratom funding for this type of research;

- the paramount importance of guaranteeing an adequate supply of experts and trained workers — in view of the increasing demand across all disciplines, coupled with the ageing and imminent retirement of a generation of experts — and the role that the Euratom programme, as a research and training programme, can and should play in ensuring that supply.

2. CHALLENGES AND OBJECTIVES

2.1. Key features of the ongoing Euratom programme

Key features of the current Euratom research and training programme 2014-2018 are:

- A **five-year cycle** (2014-2018) with a budget of **EUR 1.6 billion**. The Council may extend the programme for two years to match the seven-year duration of the Horizon 2020 Framework Programme and MFF.
- **Support for nuclear research in Europe, with a focus on safety**, waste management and radiation protection, as well as nuclear security and safeguards.
- Allocation of **research funding** through an EU-wide competition based on **excellence** as the guiding principle and main evaluation and selection criterion[15].
- **Central management** of the programme by the Commission.

The Euratom research and training programmes have been implemented by the Commission since 1959. The 2014-2018 programme provides funding for nuclear research in nuclear fission and fusion. Fission research covers nuclear safety, security, safeguards, waste management and radiation protection. Fusion research deals with the development of fusion energy. The Council Regulation establishing the current programme sets out the broad lines of action and the budget envelope. The Euratom work programmes for direct and indirect actions define the detailed priorities, budget and instruments to be used, usually on a biennial basis.

[15] Funding for indirect actions only. Funding for direct actions is decided in the basic act by the Council

The Commission implements the programme through direct and indirect actions. The 'direct actions' concern research carried out by the Commission through its JRC and are focused only on fission research (nuclear safety, safeguards and security, radioactive waste management and radiation protection, including support for the relevant EU policies). The 'indirect actions' concern research carried out by trans-European project consortia of private and public research groups. They address not only the safety of nuclear systems, waste management and radiation protection, but also the feasibility of fusion as a power source. Consequently, the indirect actions of the Euratom programme concern both nuclear fission and fusion.

Table 4 illustrates the different types of instruments used by the programme and the budget allocated to them.

Table 4 — Types of funding instruments in the Euratom Programme and % of budget allocated

Category of funding instrument	Sub-categories	Purpose of instrument	% of total budget
Grants	EJP	European Joint Programme Cofund actions designed to support coordinated national research and innovation programmes (31% of total Euratom budget)	48 %
	RIA	Research and innovation actions to fund research projects tackling clearly defined challenges, which can lead to the development of new knowledge or a new technology (17% of total Euratom budget)	
	IA	Innovation actions focused on closer-to-the-market activities (prototyping, testing, demonstrating)	
	CSA	Coordination and support actions to fund the coordination and networking of research and innovation projects and programmes	
Direct JRC actions		Funding for research carried out by the Joint Research Centre of the European Commission	35 %
Contracts based on Article 10 of the Euratom Treaty		Contracts between the Commission and research infrastructure operators, providing researchers with access to the infrastructures	16 %
Loan-based financial instruments	InnovFin	Loans to support fission R&I projects for the construction or refurbishing of research infrastructures	1 %
Prizes	Recognition Prizes	Financial prize following a contest in order to recognise past achievements and encourage future activities	<1%

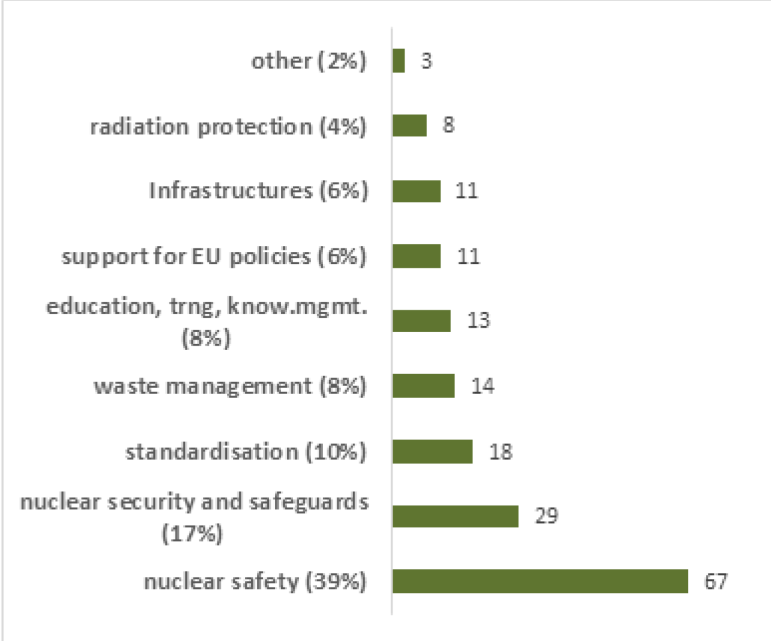
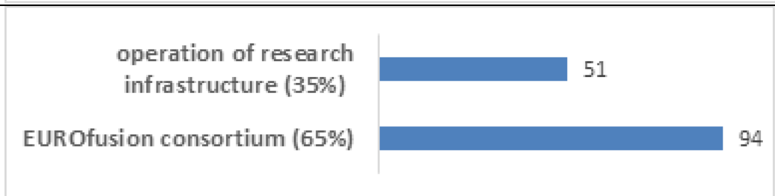
Source: European Commission

The bulk of the budget (almost half in all) is used for different types of grants, including EJP Cofund actions, collaborative research and innovation actions, coordination and support actions and innovation actions. Direct research actions implemented by the JRC[16] form the second most important category. The third is made up of contracts supporting the use of research infrastructures in fusion research (based on Article 10 of the Euratom Treaty). Other types of actions include recognition prizes and financial instruments.

[16] Research is carried about by JRC institutes in Geel (BE), Karlsruhe (DE), Ispra (IT) and Petten (NL)

As for research priorities, 55 % of the programme's budget is allocated to fission research[17], in particular nuclear safety, security and safeguards (see Table 5). This research is implemented through all instruments available to the programme, except Article 10 contracts. The programme's second priority, accounting for 45 % of the total budget, is fusion research, implemented mainly via EJP Cofund and an Article 10 contract.

Table 5 — Fields of research funded, instruments used and budget allocated under Euratom research and training programme 2014-2018

Field	Average annual budget	Funding instruments used	Annual average budgets per subfield of research (in millions of euros and in %)
Nuclear fission*	175 (55%)	Direct actions, EJP, RIA, IA, CSA, InnovFin	
Fusion energy	145 (45%)	EJP, Article 10 contracts, prizes	
Total	320 (100%)		

* Combined data for direct and indirect actions. Source: European Commission

The key feature of the programme is the way detailed priorities and assigned budgets are established through work programmes in close consultation with Member States and research stakeholders.

The Euratom direct actions consist of research activities managed and carried out by the JRC on its different nuclear sites. The work programme for direct actions is a biennial rolling programme revised every year. After a planning phase performed by the JRC, the work programme is sent via inter-service consultation for comments from other Commission departments, and to the JRC Board of Governors (composed of representatives from Member States and associated countries) for their opinion. Once

[17] Direct and indirect actions together.

their feedback has been received and processed, the programme is formally adopted in a Commission implementing decision[18], including the key orientations for the JRC work programme[19].

The work programme for indirect actions defines details of the corresponding open calls for proposals. After the Programme Committee (consisting of Member State representatives) has given its view, the Commission formally adopts the Euratom work programmes. Applicants from industry, academia, national nuclear research centres and other stakeholders submit proposals in response to calls; these are then evaluated by panels of independent experts. The list of proposals to be funded has to be approved by the Programme Committee.

Research in fusion energy is implemented by a named beneficiary, the EUROfusion consortium. This consortium, whose members are nominated by the Member States and associated third countries, has a mandate to implement the European fusion roadmap through the EJP with a rolling annual work plan.

2.1.1. What will be the Euratom programme's expected impacts under the next MFF (2021-2027) with an unchanged policy (baseline scenario)?

The continuation of the ongoing programme is expected to promote scientific excellence in nuclear research in Europe, generate new knowledge in the nuclear field and maintain nuclear skills for nuclear safety, safeguards, security, waste management and radiation protection. The future programme with the present objectives (unmodified from its predecessor) will keep delivering impacts in the key areas (see Table 6). Although the specific objectives will remain unchanged, the detailed research priorities may shift in line with evolving needs and be reflected in the biennial work programmes adopted for direct and indirect actions.

Table 6 — Expected impacts of the Euratom programme 2021-25 with unchanged policy (baseline)

Field	Expected impacts
Nuclear safety	Reinforcement of nuclear safety thanks to the research support for the development of: - accident management strategies mitigating accidents' consequences - updated knowledge on fuel properties under normal and accidental conditions and on the ageing and safe long-term operation of nuclear power plants (NPPs). - updated tools and models for safety assessments on operating NPPs, pre-normative materials qualification - safety and risk assessment of different innovative concepts of NPPs and minimisation of long-lived waste Research results will help Member States implement the 2014 Nuclear Safety Directive
Nuclear security	Improved nuclear security due to: - better knowledge of how to mitigate the risks associated with radioactive materials outside regulatory control - better detection and identification (forensics), closer cooperation and greater exchange of knowledge - optimised response to security threats through training activities and transfer of knowledge

[18] C(2017) 1288 final, Commission Implementing Decision of 28 February 2017.
[19] C(2017) 1288 final, ANNEX 1: Key Orientations for the Multi-Annual JRC Work Programme 2017-2018.

Nuclear safeguards	Euratom and international safeguards systems rendered more effective by: - enhancing the measurement capacity for nuclear materials - testing and developing integrated solutions, techniques and models for safeguards - developing further concepts and analysis of open source and trade information
Nuclear standards	- Pre-normative research on nuclear structural materials, resulting in codes and standards, novel test techniques and advanced inspection procedures - Development of nuclear reference materials, standards and measurements for benchmarks to control environmental radioactivity measurements and to check conformity assessments
Radioactive waste management	Safer management and disposal of radioactive waste thanks to: - better knowledge of the safe start of operations of geological disposal facilities for high-level radioactive waste/spent nuclear fuel - research support to help Member States make progress with their national programmes for waste management in line with requirements of Directive 2011/70/Euratom - mitigation of the risks associated with the management of high-level radioactive waste by developing models for safe disposal and improved design and technologies in support of the facilities - safe management of innovative spent fuels and waste (small modular reactors, accident-tolerant fuels) - improved standards and technology for the characterisation, management and disposal of other radioactive waste categories
Radiation protection	Higher health protection for individuals subject to occupational, medical and public exposure to ionising radiation, thanks to: - better knowledge of the long-term effects of low doses of radiation - a higher level of emergency preparedness - more effective monitoring of radioactivity in food and on the environment, and more standardised measurement methods - better knowledge of the effects of the exposure to ionising radiation used for medical diagnosis and treatment and how to reduce it Research results will help Member States implement the Basic Safety Standards Directive
Fusion energy	- A significantly expanded knowledge base of ITER-relevant fusion science will increase ITER's chances of achieving its goals of proving the feasibility of fusion for power generation. - Developments in fusion technology will allow for the start of the conceptual design phase for a demonstration fusion power plant - The development of high-tech solutions in the field of fusion technology will, with an appropriate technology transfer programme, generate spin-offs that benefit industry, the economy and society in areas beyond fusion applications
Education and training	- Preservation of knowledge and improved transfer between generations and across national programmes in nuclear fission - Training scientists and engineers will secure the human resources needed to run ITER and design future fusion power plants - Knowledge management activities will guarantee that experience from the ITER project will be retained and fed into work to design and construct a demonstration fusion power plant
infrastructures	Support for the availability and accessibility of relevant fission and fusion research facilities will bring all specific objectives of the programme closer. Examples of specific impacts: - the scientific/technical basis for power handling components of a fusion power plant - prototyping of technology for a fusion materials testing facility will provide the information needed to start the construction of such a facility - Sharing facilities will put them to full use, step up collaboration and allow for hands-on training
Support for policy	- Nuclear and ionising policy formulation based on sound scientific advice - Harmonisation of safety assessment methods, standards and tools and sharing of best practice for better implementation of directives in nuclear safety, spent fuel and radioactive waste management - Monitoring of and support for policy implementation - Trustworthy evaluation of policy effectiveness and impact

Negative impacts of the baseline scenario will be as follows:

- Limited (sub-optimal) impacts in **education and training** (no introduction of MSCAs) would result in a shortage of skilled and experienced staff in the nuclear and radiation field. At the international level, the EU might lose its position as world leader in nuclear and radiation technologies and might not be able to play an active role in spreading its high nuclear safety standards and safety culture. There would be insufficient expertise to operate fission technologies and a lack of specialised skills and knowledge transfer in both industry and science.
- Limited development **of knowledge management** would lead to loss of knowledge needed for the safe operation of existing reactors, for the management of spent fuel and radioactive waste (including repositories) and for the highest level of safeguards and security, and could lead to a defective transfer of knowledge.
- Limited **networking, infrastructure-sharing and open access** programmes would result in sub-optimal exploitation of existing and new infrastructures. The lack of new investment and key research infrastructures in fission would be a major hindrance. Hence the genuine need to pool resources at all levels (both private and public and at EU, national and regional levels) to overcome such obstacles.
- Limited emphasis is given in the baseline scenario to **nuclear science and ionising radiation technology applications**. The radiation protection aspects of the effects of ionising radiation used for medical diagnosis and treatment on patients are included. However, the safe use of nuclear science and ionising radiation technology applications for medical, industrial, space and research applications is an important area which is not sufficiently covered in the baseline scenario. This could mean higher risks of population exposure to ionising radiation in medical treatments, or of environmental exposure to natural or man-made forms of radiation.
- Unless the most is made of the **synergies** between direct and indirect actions **in the Euratom programme** and between the Euratom programme and other thematic areas of the Horizon Europe, future research programmes programmes will not maximise their impact in areas such as nuclear safety, waste management, radiation protection, medical applications of radiation, research infrastructures, etc.
- The **success of ITER** implies maintaining the level of support that is currently provided from the coordinated operation of the various infrastructures in the programme. In addition to this, a forward-thinking programme must make available new research infrastructures of relevance to ITER and DEMO[20]. These might include a high magnetic field superconducting tokamak and a fusion neutron-relevant materials testing facility. If the necessary resources for such facilities and the accompanying research, training and education actions (including access to MSCAs) are not forthcoming, the successful operation of ITER and the design of DEMO will be significantly damaged, bringing delays to the programme and associated increases in costs.
- No clear direction on **decommissioning** research may lead to delays in implementing decommissioning strategies and modern techniques, and may give rise to shortcomings in sharing best practice and knowledge on decommissioning.

[20] Demonstration power plant that will generate fusion electricity, the next step after ITER in the Fusion Roadmap

2.1.2. Main challenges and problems to be addressed by the Euratom programme 2021-2025

The future Euratom research and training programme should address the following research challenges:

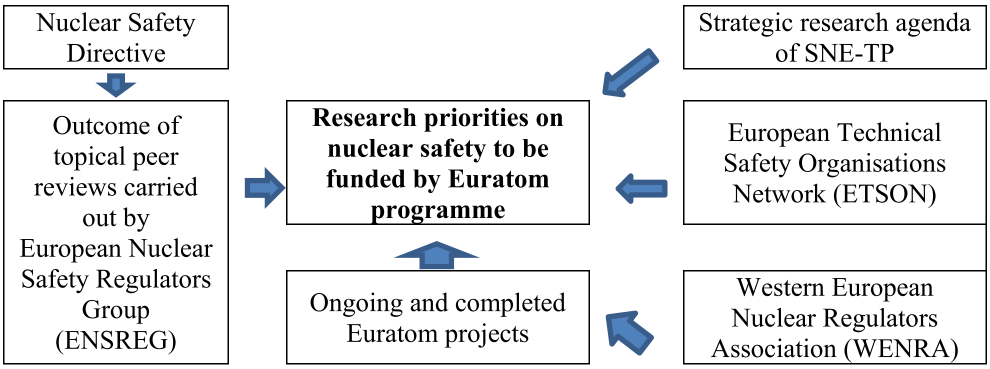
a) Nuclear safety

The safety of nuclear energy production in the EU — and the safety of other nuclear installations such as spent fuel storages and fuel enrichment and reprocessing plants — are the primary responsibility of NPP operators supervised by independent national regulators. An EU-wide approach to nuclear safety is important, since a nuclear accident could badly affect countries across Europe and beyond. Following the Fukushima-Daiichi accident in 2011, Council Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations was revised. The 2014 Directive[21] introduces a high-level, EU-wide safety objective to prevent accidents and avoid radioactive releases outside a nuclear installation. For plants already in operation, this objective should lead to the implementation of practical safety improvements. For future plants, significant safety enhancements are planned, based on the scientific and technological state of play. The Directive highlights the need for Member States to use research results in its implementation and creates a system of peer reviews.

The research priorities in nuclear safety are continuously evolving (see Figure 1) in line with the state of the art, as witnessed from the feedback from ongoing Euratom projects, updated strategic research agendas (SRAs) from technology platforms such as SNE-TP (NUGENIA), and feedback from implementation of the 2014 Safety Directive. In this regard, the results of the topical peer review on ageing management of nuclear power plants organised by European Nuclear Safety Regulators Group (ENSREG), expected in 2018, will serve as important input for the research agenda. Other leading stakeholders providing inputs are ETSON and WENRA (see Figure 1 below). On this basis, the Commission can ensure that the work programmes containing future calls for proposals funded by the Euratom programme are up-to-date and address current needs, including safety assessments for any innovative concepts.

[21] Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations, *OJ L 219, 25.7.2014, p. 42–52*

Figure 1 — Overview of inputs for establishing research priorities in nuclear safety



An example of detailed feedback on current research priorities is given in Table 7 below.

Table 7 — Stakeholder feedback on current research priorities in nuclear safety **Input from European Technical Safety Organisations Network**	
- Safety assessment methods (safety margins methodology, deterministic and probabilistic approaches) - Multi-physics multi-scale safety approach - Ageing of materials for a long-term operational perspective - Fuel behaviour (loss of coolant accident, RIA or reactivity insertion accident, criticality) - Human and organisational factors in safety management - Instrumentation and control (I&C) systems	- Internal and external loads and malicious acts (integrity of equipment and structures, fire propagation, etc.) - Severe accidents phenomenology and management - Emergency preparedness and management - Extreme natural and unintended man-made hazards - Preventing and controlling abnormal operation and failures - Defence in depth — prevention of (severe) accidents through decay heat removal from the reactor core and the spent fuel pool (SFP), and secondly the protection of the containment integrity. - Controlling severe conditions, including prevention of accident progression and mitigation of severe accident consequences

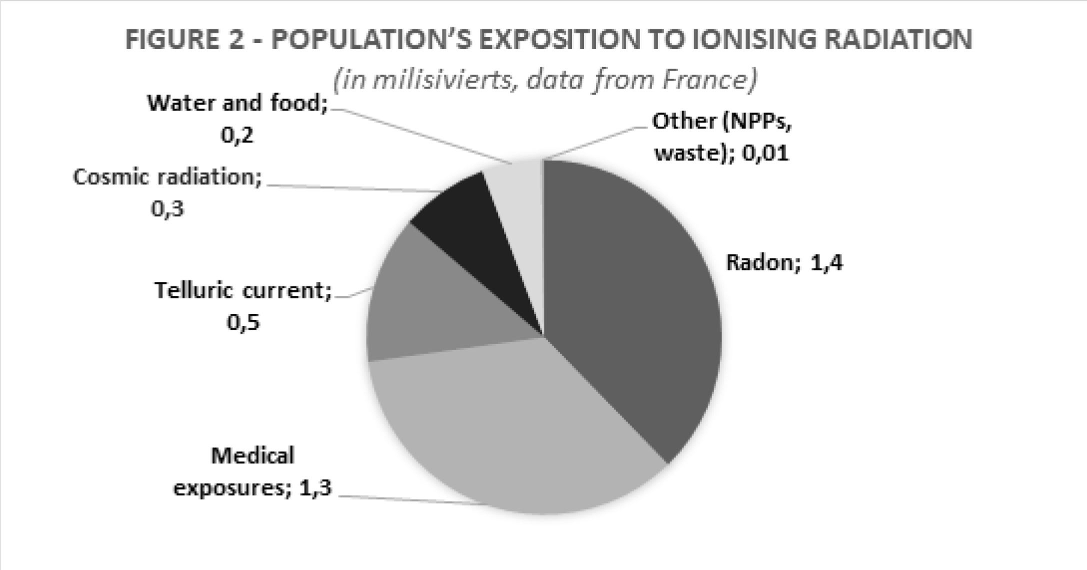
Source: ETSON views on R&D priorities for implementation of the 2014 Euratom Directive on safety of nuclear installations, Kerntechnik 81(2016), Position paper of the technical safety Organisations: Research needs in nuclear safety for GEN 2 and GEN 3 NPPs, October 2011

b) Radiation protection and ionising radiation applications

A growing number of different applications of ionising radiation requires protection of the people and the environment from unnecessary exposure to radiation. Ionising radiation technologies are used every day in Europe in a number of fields such as health, industry and research, providing large benefits to European citizens and European economy[22]. Research plays key role, providing for better understanding of harmful effects of radiation from natural and artificial sources, and expanding beneficial applications of radiation technologies.

[22] European Study on Medical, Industrial and Research Applications of Nuclear and Radiation Technology, 2018

Naturally occurring radioactive isotopes of uranium, thorium, potassium and carbon constitute Europeans' main source of exposure to radiation. Almost equally important are X-rays, used in medical diagnostics or therapy, whose contribution is increasing as medical procedures continue to rise (see Figure 2).



Source: ASN, 2010

Low dose research

At the European level, efforts have been under way since 2007 to establish and bring together European platforms for radiation protection research in the five key areas of low dose risks, dosimetry, emergency and preparedness, radioecology and medical applications. The platforms concerned are MELODI, EURADOS, NERIS, ALLIANCE and, more recently, EURAMED. Following the establishment in 2015 of the European Joint Programme in radiation research (CONCERT), all of these platforms have entered into close cooperation, including the development of SRAs, listing the general and specific research priorities within their disciplines[23].

These SRAs indicate that a key priority for radiation protection research is to improve health risk estimates for cases of exposure matching the dose limits for occupational exposure and the reference levels for the exposure of the population in emergency situations.

In addition, new challenges have emerged recently with the adoption of the Basic Safety Standards Directive that regulates practices involving ionising radiation in fields such as industry and medicine[24].

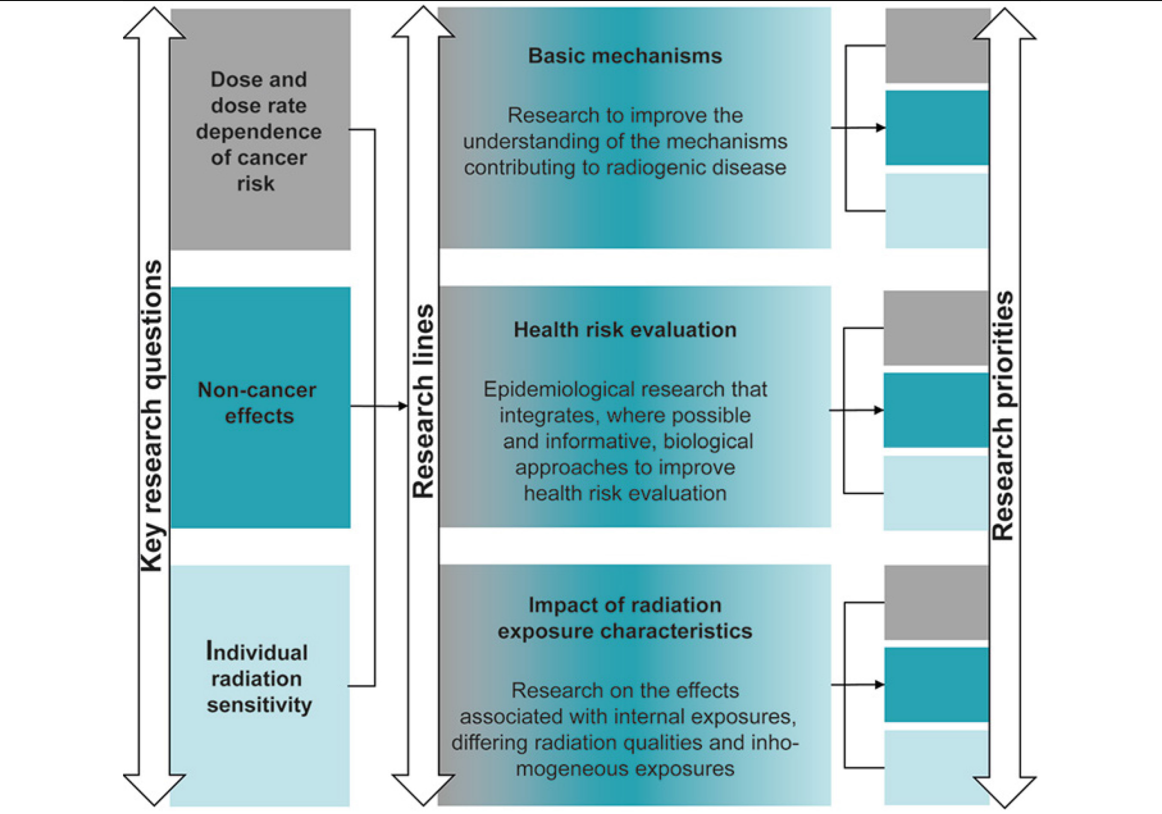
Recent tests carried out by the JRC in Member State laboratories highlighted major gaps in monitoring radioactivity in drinking water and in air. These should be addressed through support for measurement laboratories. For there to be comparable data between Member State laboratories, further work will be needed on primary standards, reference materials and measurement methods.

23 http://www.er-alliance.org/assets/files/attachments/ALLIANCE%20gap%20analysis_Feb%2020.

24 Council Directive (2013/59/Euratom) of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom.

The main uncertainties in radiation health risk evaluation are in the magnitude of cancer risk at low and protracted doses below 100 mSv, the magnitude of non-cancer effects below 500 mSv and the variation in disease risk between individuals in the population. Therefore, the key research questions are: the dose and dose-rate relationship for cancer; non-cancer effects; and individual radiation sensitivity (see Figure 3).

Figure 3 — Key research questions for low dose research



Source: MELODI

Research at low dose rates or low doses presents significant challenges in the investigation of both radiation-related health effects and underlying biological mechanisms because the magnitude of health risk and biological effects is expected to be low. A multidisciplinary approach is therefore essential.

Medical applications of radiation

The health domain is by far the most important domain in Europe, where ionising radiation is used in terms of the number of people affected and from an economic perspective (employment, market and its growth rate). Radiation technologies are used in the health sector, both for diagnostics (imaging) and treatment (therapy). There are about 100 different nuclear imaging procedures available today and over 10 000 hospitals worldwide use radioisotopes; the vast majority of the medical procedures (about 90 %) are for diagnosis[25].

[25] Report to the European Commission (SWD(2015) 179) on activities following on from the Council conclusions of 15 December 2009 on the security of supply of radioisotopes for medical use and the Council conclusions of

Recent increases in medical imaging, particularly with respect to computed tomography (CT) and other high-dose procedures, have led to a significant increase in individual patient doses and in the collective dose for the population as a whole. Regular assessments of the magnitude and distribution of this large and increasing source of population exposure are therefore crucial. The overall per capita effective dose for all medical imaging (X-rays and nuclear medicine procedures) is about 1.12 mSv. The contribution to the total population dose of different procedures is as follows: CT (57 %), plain radiography (17 %), fluoroscopy (12 %), interventional radiology (9 %), and nuclear medicine (5 %)[26].

Development of imaging technologies has to be followed, in order to ensure the fast deployment of dose limitation devices. The clinical applications of imaging techniques using ionising radiation are very wide. On the other hand, the therapeutic clinical applications of ionising radiation are essentially focused on cancer treatment. Such therapies use high-energy particles or waves, such as X-rays, gamma rays, electron beams or protons, to destroy or damage cancer cells.

In view of the above developments, research challenges for the next 5-10 years must focus on:

- promoting the deployment of dose reduction functionalities in CT and supporting research on evolutionary CT technologies to reduce the dose to patients during CT;
- developing new radioisotopes (other than Mo-99/Tc-99m) for cancer treatment;
- monitoring better the doses received by patients from medical applications; and
- reducing the high variability in radiation doses between hospitals.

Other applications of radiation

Beyond their extensive use in medicine, ionising radiation (IR) technologies are present in a large variety of applications in industry, applied research, agriculture, environment or security, and their beneficial use could be further extended by research, in particular in dose reduction and provision of adequate standards and skilled personnel. The growth potential of new innovative industrial applications based on these IR tools is very large. For instance, nanoparticles (NPs) and nanostructures manufactured with IR tools may be used in a number of areas. Recent advances in particle accelerator technology could be beneficial for many energy and environmental applications, such as treating drinking water, waste water, and sludge, removing pollutants from stack gases, treating medical waste, conducting environmental remediation of hydrocarbon contaminated soil and conversion of fossil fuels. They may also have synergetic effects in other strategic domains (magnetic separation and superconducting technologies) like increasing the capacity of wind generators, enhancing the magnetic separation of material streams, and increasing the efficiency of electrical power transmission[27].

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6 December 2010 and 7 December 2012 entitled 'Towards the Secure Supply of Radioisotopes for Medical Use in the European Union'.

[26] RADIATION PROTECTION N° 180, *Medical Radiation Exposure of the European Population*, European Commission, 2015.

[27] European Study on Medical, Industrial and Research Applications of Nuclear and Radiation Technology, 2018

c) Waste management

Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste reaffirms that, ultimately, Member States are responsible for managing the spent fuel and radioactive waste they generate. This includes establishing national policies and implementing them under national programmes. The Directive lays down requirements concerning research as an integral part of their respective national programmes.

The key scientific and technical challenge in radioactive waste management remains the implementation of the disposal options for spent fuel and high-level radioactive waste over a very long time-scale (from hundreds to thousands of years). Research should reduce uncertainties in the safety assessment and demonstration of disposal, and provide analytical tools and methods to deepen understanding of ongoing processes and mechanisms at disposal sites. One important issue around geological disposal is about ensuring appropriate knowledge management and transfer between generations who will be responsible for managing disposal sites.

Research should also address issues concerning the management and disposal of other types of waste and streams, including legacy and pre-conditioned waste, waste from experimental and fuel cycle developments and waste from reactor dismantling, for which no appropriate management and disposal solutions are available. The traditional concepts for research on waste management are also subject to evolution. Waste resulting from accident-tolerant nuclear fuels, developed following the Fukushima accident, and from innovative future reactors present new challenges for disposal which need to be determined and assessed.

d) Decommissioning of nuclear installations

The decommissioning of nuclear power plants will become an increasingly important activity for the European nuclear industry in the coming years, due to the ageing fleet. However, experience in this field is rather limited[28]. Ninety power reactors in the EU have been shut down, but only three had been completely decommissioned (all in Germany). The international view does not offer much broader experience: although today 166 reactors are in permanent shutdown mode worldwide, only 13 have been completely decommissioned: in addition to the aforementioned three in Europe, all of the others are in the United States. By 2025, it is estimated[29] that over a third of the EU's currently operational reactors will be at the end of their lifecycle and in need of shutdown. This equates to 40 additional reactor shutdowns and a total fleet of 130 reactors across the EU undergoing or awaiting decommissioning.

Though various dismantling techniques are already industrially mature, there are still specific challenges regarding achieving high safety levels for dismantling operations. Public research has a potential role to play in supporting safe decommissioning and in reducing the environmental impact of decommissioning.

The EU must be better prepared for the emerging decommissioning market, and for safe dismantling and management of resulting radioactive waste. This requires the development of standardised practices, innovative technologies for waste and site

[28] PINC, SWD(2017) 237 final.

[29] https://ec.europa.eu/energy/en/topics/nuclear-energy/decommissioning-nuclear-facilities

characterisation, and the use of safeguards in nuclear decommissioning. In turn, all of these rely on scientific and technical support. A roadmap for decommissioning research, resulting from a project to be launched under the Euratom work programme for 2018, will provide guidance to stakeholders and the Commission on the steps needed during the next 10-15 years for the development of knowledge on decommissioning and its safety, economic and environmental aspects. It should support future coordination of R&I efforts, which currently tends to be sporadic and overlapping.

e) Nuclear security and safeguards

The main purpose of nuclear safeguards is to assure that nuclear materials are only used for their declared civil use and are not diverted for non-peaceful applications. The detection and the identification of illegally transported or stored nuclear material constitute a major line of defence against illicit trafficking.

According to Chapter 7 of the Euratom Treaty, the European Commission must fulfil its safeguarding obligations, in particular safeguarding existing radioactive materials in the EU and the obligations relating to the non-proliferation of nuclear weapons.

The role of research is to develop and improve analytical techniques and methodologies for safeguarding nuclear materials and to provide operational support to safeguarding authorities[30]. Different innovative concepts for safeguards and non-proliferation such as the analysis of nuclear energy systems (safeguards by design, proliferation resistance evaluation, etc.), along with various sources of information, will need to be explored to deal with non-proliferation and security issues in the coming years.

Further research is needed to support nuclear security technologies, above all detection and nuclear forensics, to respond to a nuclear security event and provide substantial training in the field. To prevent the worldwide proliferation of weapons of mass destruction and other sub-national threats, scientific support for the harmonised implementation of trade controls must also be provided.

f) Maintaining nuclear competences and knowledge management

Using of nuclear technologies in all areas of application as well as nuclear safety and security require a highly specialised workforce and preservation of the present knowledge base. Regardless of whether or not new nuclear power plants are built in EU Member States, for several decades there will be an ongoing requirement in the regulatory bodies and the industry to recruit qualified staff. Not only the nuclear power sector, but also those industrial and medical applications making use of ionising radiations, together with fusion energy research, will require highly educated staff with very specific knowledge, skills and competences. The rapid advances in, and growing use of, radiation-based medical imaging are also giving rise to particular concerns regarding the education and training of medical professionals.

The overall workforce situation in the EU (and worldwide) is at risk as highlighted by several reports and studies[31]. The challenge arises partly from the age profile of staff in nuclear fields (staff in the 45-65 age bracket account for more than half of the workforce). Because of retirements over the next decade or so — and partly because of a decline in the numbers of students graduating from courses in nuclear science and

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[30] JRC research and development in nuclear safeguards, https://ec.europa.eu/jrc/sites/jrcsh/files/jrc-research-development-nuclear-safeguards.pdf.

[31] http://ehron.jrc.ec.europa.eu/.

engineering and filling the vacancies left by retirees — much of the current nuclear knowledge base could be lost[32]. This decline is possibly caused by the perceived lack of professional career prospects. It is also becoming increasingly difficult to interest graduates from technical and other studies in taking up a job in the nuclear sector. Moreover, the European sector is rather unattractive for foreign talent, to the development of professional opportunities in nuclear field in other regions.

Knowledge management and knowledge transfer between generations and Member States is essential for maintaining the EU's high safety standards in all nuclear activities.

g) Fusion energy

EU decarbonisation efforts are currently supported through the development of renewables, improvements in energy efficiency, and use of nuclear fission. In this context, all existing energy sources have their disadvantages and limitations. Use of nuclear fission requires continuous safety improvements, development of radioactive waste disposal and reduction of risks related to nuclear proliferation.

On a longer timescale, fusion energy is a possible new complementary option for low carbon electricity production, which could help address climate change and a growing energy demand. Fusion would be a continuous energy source that does not face the same safety risks, limited waste and proliferation issues as fission, and does not require disproportionate land use. To prepare Europe for fusion deployment, the research and technology development must first demonstrate the scientific and technical feasibility of fusion energy, and then demonstrate its commercial and economic viability. If found to be a viable new energy source, it could contribute significantly to the well-being of future generations. The main impacts of fusion energy deployment could be:

- Improvement of environmental performance of EU energy sector
- Contribution to the mitigation of climate change and to EU energy security
- Improvement of the EU innovation and competitiveness.

Fusion research is a long-term endeavour due to the need to master hot plasmas in large facilities and to develop materials able to withstand very high temperatures and extreme conditions. For this reason, potential deployment of fusion power plants and their contribution to the decarbonisation of the energy mix in Europe cannot be realistically foreseen until the latter part of the century. Fusion could come on line later in the century, as electric power needs are predicted to double between 2050 and 2100. These are all arguments for continuous efforts to demonstrate fusion's feasibility at industrial level, taking into account that all different energy sources will play a key role in completing a coherent energy-mix for future societal development.

Organisation of fusion research

Fusion science and technology has now reached the next stage of development thanks to the successful exploitation of research facilities and progress in the construction of ITER, a research facility under construction in south of France with the aim of demonstrating the scientific and technological feasibility of fusion on Earth as a sustainable energy source. The European Joint Programme (EJP) for fusion research supported by the current 2014-2018 Euratom Programme, which provides 55% of the total funding, plays

[32] Number of students in nuclear fields in EU (2012 EHRON data): ~500 Masters, ~650 Bachelors, ~800 PhD (~100 in fission and ~700 in fusion (2017 data)).

a crucial role in this process. It is implemented by the EUROfusion consortium, consisting of all national fusion labs and institutes in Europe (under the 2014-18 programme the Commission has a separate contract for the operation of the JET facility which is exploited by EUROfusion). This comprehensive and goal-oriented project covers all aspects needed to realise fusion energy. It includes joint research, use of shared facilities, mobility of researchers, industrial involvement, education and training, international cooperation, etc. The activities of the EUROfusion consortium are focussed on the implementation of the fusion roadmap to fusion electricity[33], which was approved in 2012 by all European labs as the long-term guiding strategy. After an adoption of the new ITER baseline[34] in 2016, EUROfusion proceeded in 2017 with an update of the roadmap to ensure that it reflects the latest state of play in fusion R&D and that it provides a strategic guidance for the organisation and execution of fusion R&D in Europe.

The establishment of the EUROfusion consortium in 2014 was a key step in this major reorganisation of the fusion research in Europe. The EJP allows considerable flexibility within the consortium to organise and implement research and related activities. The consortium has the complete freedom to allocate the Euratom funding to the beneficiaries according to its own internal procedures. Compared to the fusion research before 2014, the involvement of the Commission's services is focussed on the broad strategy to achieve fusion as laid out in the roadmap by ensuring that EUROfusion delivers as planned. The Commission pays for the implementation of the roadmap in annual instalments based on the achievement of specified goals in the annual work plans. This should be continued in the next 2021-2025 Euratom progamme to all aspects of the fusion research including the funding and use of all relevant infrastructures.

The fusion roadmap provides a list of 8 R&D missions addressing the main scientific and technical challenges for the realisation of fusion energy. Of these 8 missions, 4 of them require the use of highly specialised research infrastructures in addition to ITER (see table below).

[33] https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/
[34] ITER baseline defines scope of the project with regard to performance capabilities, schedule and costs

Main fusion scientific and technical challenges (research missions)	What is needed to achieve mission?	Infrastructures (existing and future devices which fulfil requirements of the missions)
Mission 1 - Plasma regimes of operation: demonstrate plasma scenarios (i.e. ability to manage hot plasma without disruptions) that increase the success margin of ITER and satisfy the requirements of demonstration power plant	Mission 1 will be achieved in ITER. Before start of ITER exploitation, the research programme needs to investigate operating scenarios for ITER and optimise control measures on the basis of similar fuel mix (deuterium and tritium) and with the same combination of plasma facing materials as planned for ITER.	JET[35] JT-60SA (available from 202X, in Japan) Different Medium-sized tokamaks (available now)
Mission 2 - Heat-exhaust systems: demonstrate a system that can handle the large power leaving ITER and DEMO plasmas.	ITER will test if the existing heat–exhaust system (divertor) will provide a sufficient performance needed for fusion power plant. To address possible risks of lower than expected performance there is a need to develop alternative concepts that require specific infrastructures.	Divertor Testing Facility (planned in Italy by 2023-25)
Mission 3 - Neutron tolerant materials: develop materials that withstand the large 14MeV neutron flux for long periods while retaining adequate physical properties.	Currently available plasma facing materials for ITER were developed on the basis of fission neutron irradiation campaigns, not covering fully the temperature and other operational conditions of fusion power plant. A powerful fusion material neutron source with a fusion-like neutron spectrum is mandatory for the validation and qualification of materials for the demonstration power plant, in particular for licensing and regulatory authorities.	IFMIF-DONES (planned in Spain by 2023-2025)
Mission 8 - Stellarator: bring the stellarator concept to maturity to determine the feasibility of a stellarator based power plant.	Further investigation is needed to check if stellarator concept is able to deliver and control high performance plasma.	W-7X stellarator (operating since 2016)

Source: Fusion roadmap

In addition to the missions described in the table above, all research activities are underpinned by the need for a strong numerical modelling. It is therefore important to ensure that the fusion programme embraces developments in computation, especially towards exascale computing[36]. This will not only require investment in High Performance Computing hardware, but also a significant evolution in the implementation of numerical models to ensure they work efficiently with exascale computer architectures. The challenge is to adapt the current practises and provide much closer integration of researchers and programming specialists. Furthermore, much greater emphasis on validation of numerical modelling will be required for numerical models to play a role in DEMO development.

[35] In line with the Commission proposal for extension of the Euratom programme until 2020, the current contract for JET operation will be extended until 2020 when the facility will be handed over to UK.

[36] Exascale computing refers to computing systems capable of at least one exaFLOPS, or a 10^{18} calculations per second

The fusion roadmap specifies in detail what input is needed from different research facilities in order to address all missions. In addition, the roadmap lists decisions concerning the use of fusion research facilities according to their impacts on the implementation of the roadmap, especially until ITER comes into operation[37]. These decisions are as follows:

- The decision on a possible exploitation of JET after 2020
- The decision on the test facility for alternative tokamak exhaust configurations;
- The decision on the future exploitation of the JT-60SA in Japan;
- The decision on the Early Neutron Source (IFMIF-DONES).

The nature of the involvement of the EUROfusion consortium in each of the above facilities/projects after 2020 should be decided by the consortium on the basis of the scientific and technical knowledge available in order to ensure a successful implementation of the roadmap and the rate of construction of the different facilities where necessary. The role of the Commission services is to provide strategic oversight and ensure that the grant for EUROfusion is used effectively and that EUROfusion reaches subsequent roadmap's milestones.

Challenges for fusion research

During the 2021-2027 MFF fusion research will face two major research challenges:

- extending the physics/technology basis of ITER relevant fusion science to ensure that future ITER operation will be effective and efficient;
- completing a conceptual design of a demonstration fusion reactor (a DEMO) that generates electricity, and starting transitioning into an engineering design phase of DEMO.

For future ITER operation to be successful and efficient, it is crucial that the science base is well understood. In particular, the scenarios for operation of ITER should be tested to ensure they are robust and will have a good performance. Potential problems must also be identified and as much as possible addressed before ITER exploitation starts, because it will be much costlier to resolve issues on ITER itself. This will require a broad experimental programme on existing fusion devices, especially those with the greatest ITER relevance, and complemented by an extensive analysis and simulation programme. A potential problem in this respect could be access to devices that in terms of size and components composition are highly ITER relevant.

In order to achieve the goal of completing a pre-conceptual DEMO design and starting the transition to an engineering design phase in the next MFF, the focus of the fusion programme must gradually shift from physics to technology. Consequently, a continuation and even acceleration of the reorientation of the programme towards fusion technology that started during the 2014-18 Euratom programme is necessary. However, changing the composition of researchers in the fusion programme cannot happen overnight, and it will take a sustained effort to redress the balance between physicists and engineers. Furthermore, as the DEMO design becomes increasingly advanced, it will be necessary to involve industry much more than is currently the case. In addition, it is also important to ensure that the engagement of industry participation is at a sufficient level already early on in the next MFF. If not, there is a clear risk that the knowledge of fusion technology now residing within industry due to the ITER construction will be lost before

[37] See section 10 of the fusion roadmap

it becomes indispensable for DEMO. Consequently, appropriate mechanisms for greater industry involvement must be put in place for the next MFF.

2.2. Objectives of the Euratom programme for the next MFF

The Euratom programme is established via a Council Regulation setting out the overall objective, overall budget and specific objectives. For each specific objective the Regulation merely outlines the research and training measures eligible for support. The Euratom work programmes for direct and indirect actions, to be adopted by the Commission after consultation with Member States, define the more detailed priorities, budget and instruments to be used. This approach will mean that the programme can be implemented with the flexibility that the new MFF is seeking across the board.

2.2.1. Main objective of the Euratom programme

The programme's overall objective remains unchanged and is based on the compromise reached unanimously in Council in 2011 following the Fukushima nuclear accident and confirmed recently by the Council's political agreement on the regulation concerning extension of the 2014-18 programme for 2019-2020. It seeks to 'pursue nuclear research and training activities to support continuous improvement of nuclear safety, security and radiation protection, and potentially contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way'. It is implemented through a number of specific objectives setting out detailed research and training activities to be funded by the programme.

2.2.2. Revision of specific objectives and overview of other changes introduced in the future Euratom programme

The programme's overall scope will remain unchanged, with a focus on:

- nuclear safety and security,
- radiation protection,
- radioactive waste management, and
- fusion energy.

To address issues raised by the interim evaluation and by stakeholders, the Commission intends to introduce a number of modifications. The modifications proposed concern the structure of specific objectives, their content, and some implementing provisions (for example on EJPs). It is also important to remember that the Euratom programme complements the Framework Programme for Research and Innovation, sharing with it the horizontal provisions and rules for participation. As a result, modifications introduced to these provisions and rules will be also applicable to the Euratom programme 2021-25.

An overview of all modifications proposed is provided in Table 8.

Table 8 — Modifications from evaluations and stakeholders to address issues		
Issues	**Modifications to Euratom programme**	
Continuation of nuclear research focused on nuclear safety, safeguards, security, radioactive waste management, radiation protection and development of fusion energy	**Modification of specific objectives**	Introduction of a single list of specific objectives for direct and indirect actions Reduction in the number of specific objectives Revision of specific objectives for decommissioning and nuclear science and ionising radiation technologies A revised specific objective for developing expertise and excellence
More research on nuclear science and ionising radiation technologies		
Research to provide solutions for **decommissioning** of nuclear installations		
Exploit **synergies between direct and indirect actions** of the Euratom programme		
Reinforce education and training actions for developing competencies in nuclear field		
	➡ Opening 'Marie Skłodowska-Curie Actions' up to nuclear researchers	
Cross-cutting actions of Euratom programme and Framework Programme for Research and Innov.	➡ Legal provisions facilitating cross-cutting actions in the Euratom programme and Framework Programme for Research and Innovation	
Support access to and more effective use of research infrastructures for nuclear research	➡ Development of legal and administrative mechanisms for the optimal use of Commission research infrastructure through open access Development of initiatives for networking and sharing of research infrastructures in Europe and for supporting access	
Knowledge management activities	Reinforced role of the JRC for the management of knowledge produced in the nuclear field.	
Improve organisation and management of the **European Joint Programmes** in nuclear research	➡ Amendment of implementing provisions for EJPs	

Detailed description of changes proposed:

- **Structure of specific objectives**: a single set of specific objectives for direct and indirect actions is introduced in the basic act. This will allow the Commission, when preparing work programmes, to propose combining instruments such as the Commission's research infrastructures and JRC's knowledge base. This approach addresses one of the MFF's cross-cutting objectives concerning synergies and simplification.
- **Revision of specific objectives** (see also Table 9):
  - **Reduction in the number of specific objectives** from 13 in the 2014-18 programme for both direct and indirect actions to four.
  - **Introduction of a specific objective on supporting the policy of the Union on nuclear safety, safeguards and security**.
  - **Definition of the research support for decommissioning** — the revised objective for radioactive waste management covers decommissioning. The scope of the eligible actions includes research activities supporting the development and evaluation of technologies for decommissioning and

environmental remediation of nuclear facilities, and sharing best practices and knowledge on decommissioning (current programme contains only a short reference to decommissioning in the safety objective). The focus on decommissioning reflects the early decommissioning demand based on the public interest, the principle of environmental remediation, and the current and future high number of permanently shutdown nuclear reactors.

  - **Revision of the scope of research for radiation protection** — it also aims to contribute to the safe use of the nuclear science and technology applications of ionising radiation, including the secure and safe supply and use of radioisotopes. Medical, industrial, space and research applications are some of the options. Any applications of nuclear science and ionising radiation should be performed based on the general principles of radiation protection as defined in the Basic Safety Standards Directive (2013/56/Euratom).
  - **Single specific objective on fusion research** to reflect the shift towards the design of future fusion power plants. The new objective for fusion research combines three specific objectives from the current 2014-2018 programme.
  - **Single specific objective for all actions necessary for maintaining and further developing expertise and excellence in the EU**. It includes education and training actions, support for mobility, access to research infrastructures, technology transfer and knowledge management and dissemination (current programme has separate objectives for these actions).
  - **Specific objective on supporting the policy of the Union on nuclear safety, safeguards and security**.

- **<u>Opening of ‘Marie Skłodowska-Curie Actions’ to nuclear researchers</u>**: new provisions proposed for Horizon Europe and Euratom will make nuclear students and researchers eligible for MSCAs. By using a well-established instrument for supporting education and training in Europe the new programme addresses one of the MFF’s cross-cutting objectives concerning synergies between funding instruments.
- **Legal provisions facilitating cross-cutting actions** in the Euratom programme and in the Horizon Europe Framework Programme: both basic acts will provide for cross-cutting actions, the details of which will be decided in the work programmes in consultation with Member States (see also section 4.1(a)).
- **Amendment of implementing provisions for European Joint Programmes in fission and fusion research:** improvements will address issues impairing mobility and funding for third parties (see also section 4.1(b)).

Table 9 — Overview of changes in the Euratom programme's specific objectives from 2014-2020 to 2021-25

Specific objectives for 2014-2020	Specific objectives for 2021-2025	Explanation of changes
Supporting safe operation of nuclear systems	**Improving the safe and secure use of nuclear energy and non-power applications of ionising radiation, including nuclear safety, security, safeguards, radiation protection, safe spent fuel, radioactive waste management and decommissioning.**	*Broader definition of nuclear safety.*
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		*Revised objective covers a broader scope of activities incl. management and transfer of knowledge and decommissioning (covering limited activities in well-defined areas).*
Supporting radiation protection and development of medical applications of radiation, including, *inter alia*, the secure and safe supply and use of radioisotopes		*Revised objective covers broader scope of research for nuclear science and ionising radiation technology applications*
Specific objectives for direct actions		*Direct actions covered by single set of specific objectives*
Supporting the development and sustainability of nuclear expertise and excellence in the Union	**Maintaining and further developing expertise and excellence in the Union**	*A single specific objective for education and training covering all actions necessary for maintaining and further developing expertise and excellence in the EU. This includes education and training actions, support for mobility, access to research infrastructures, technology transfer and knowledge management and dissemination*
Promoting innovation and industry competitiveness		
Ensuring availability and use of research infrastructures of pan-European and international relevance		
Moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities	**Fostering the development of fusion energy**	*Three 2014-2020 programme objectives merged into one, with a focus on future fusion power plants*
Laying the foundations for future fusion power plants by developing materials, technologies and conceptual design		
European fusion programme		
Policy support provided by direct actions	**Supporting the policy of the Union on nuclear safety, safeguards and security**	*Provision of policy support is maintained as a separate specific objective*

- **More effective use of research infrastructures, including European Commission's research infrastructures:** the Commission will launch initiatives facilitating mobility, networking and sharing of nuclear research infrastructures to improve education and training impacts and to optimise their use. The JRC could play an active role in enabling EU scientists interested in conducting nuclear safety research to use both its own facilities and those in the Member States, and combine these efforts with indirect actions, which allow for a consistent and sustainable approach.

- **Reinforcement of the JRC's role in knowledge management** related to nuclear science: Following its 2030 strategy and in order to cope with the specific needs in the nuclear field already described, (paragraph 2.1.2.g) JRC will analyse and communicate in a systematic manner, its own produced knowledge and also the one produced by other sources when appropriate.

- **Other changes:** in fusion research there will be minor changes to the structure and organisation of the programme. All those involved in fusion research are already embedded in the EUROfusion consortium, and the consortium is an integral part of the global European fusion community. Therefore, it will continue to be the main R&I stakeholder for the implementation of the fusion roadmap's research plan. It is envisaged that this plan will be a continuation of the current programme. However, it will also include new infrastructures of EU relevance, preparations for ITER operation and the down selection of DEMO technologies for the start of detailed engineering design activities at the end of the programme. However, the Euratom programme 2021-25 should also be seen as a transition towards more industry-led activity and during this period the structure and organisation may further evolve as ITER construction comes to a conclusion and the Fusion for Energy joint undertaking takes more responsibility for the DEMO preparation, in line with its statutes[38]. It is therefore proposed to ring-fence resources for the industrial effort, which will be managed separately from the European joint programme, with the industrial services being provided as an in-kind contribution to the EUROfusion consortium.

2.2.3. Success criteria for the Euratom programme 2021-2025

The future programme's impacts could be measured as follows:

- Use and application of research results from the Euratom -programme by end-users (nuclear regulators, NPP operators, nuclear industry, medical sector). Two yardsticks to measure this could be: (1) the participation of end-users in the projects (for the 2014/15 call the figure was 45-50 % of participants, according to an Ernst & Young

[38] See Article 1(2)(c) of the Council Decision of 27 March 2007 (2007/198/Euratom as amended by Council Decision 2015/224/Euratom) establishing the European Joint Undertaking for ITER and the Development of Fusion Energy and conferring advantages upon it: *The tasks of f4E shall be as follows: […] to prepare and coordinate a programme of activities in preparation for the construction of a demonstration fusion reactor and related facilities.* Article 3 of the f4E Statutes annexed to the above Council decision states that: *In preparation for the construction of a demonstration fusion reactor and related facilities, including the IFMIF, the Joint Undertaking shall prepare and coordinate a programme of research, development and design activities other than ITER and Broader Approach Activities.*

study, and (2) a survey on the use of programme outcomes (scientific publications, references materials and measurements, etc.) by end-users.

- Launch of an experimental campaign by ITER supported by the Euratom programme.
- Launch of geological disposal repositories supported by the EJP in radioactive waste management.
- Percentage of EU students in the nuclear field (fission and fusion, all levels) supported by different programme measures (fellowships, PhD funding, mobility etc.).

2.2.4. Implementation of specific objectives

For fusion research, the specific objectives have to be addressed both via the programme structure and priorities, and via the delivery mechanisms

In terms of programme structure it is important for fusion research in Europe that the objectives are implemented through a joint programme to ensure that all the Member States (the smaller ones included) are involved in implementing the European fusion roadmap, with its ultimate aim of producing electricity from fusion energy. This also makes for more broad-based coordination across the fusion community in the European Union and associated countries, providing access to the available infrastructures and enabling researchers to move around. Additionally, it allows for dynamic international cooperation on fusion under the Commission's strategic leadership of the.

The delivery mechanism for such research is equally important, as it has a leverage effect for the Member States. By contributing 55 % of the total costs Euratom allows the Member States to pool national resources in pursuit of the goals of the fusion roadmap and to become more involved in a Community joint effort. Also, considering that fusion is still in the research phase, it is important that the delivery mechanism is still a grant. The important role of public funding programmes in this endeavour is a reflection of its long-term objectives. Nonetheless, with the success of ITER and the demonstration of the viability of fusion energy at reactor scale, industry will become more involved. Therefore, it will be necessary to reflect on the possible use of other financial instruments — such as loans or equity — that can complement the support offered through grants.

For fission research, the same applies.

In terms of programme structure it is important for fission research in Europe that the objectives are implemented through research and innovation actions and joint programmes to ensure that all the Member States (the smaller ones included) are involved in consensus-building around the nuclear safety objectives in the relevant Directive. This key aspect of fission research should remain a priority in a programme structure defining milestones. This also makes for more broad-based coordination across the fission community in the European Union and associated countries, providing access to the available infrastructures and enabling researchers to move around. Additionally, it allows for dynamic international cooperation on fission under the Commission's strategic leadership.

The delivery mechanism for such a programme is equally important, as it has a leverage effect for the Member States. By contributing to research in fission Euratom takes advantage of Member States' experience in the field and helps build an EU safety doctrine aligned with the best Member State know-how. Also, with EU safety objectives being the highest in the world, their practical implementation using the best know-how is of paramount importance.

The direct actions of the programme, implemented by JRC, include the provision of the scientific basis for Union policies related to nuclear safety, security and safeguards, in full alignment and complementarity with MS national research programme. In fields as nuclear safeguards, the Euratom programme provides technical and scientific support to the Euratom safeguards regime and in the nuclear security field an important part of the activities performed will support the Member States with trainings and exercises. There is also a strong international dimension in the JRC's implementation of the programme, for example with IAEAto take into consideration the global dimension of the nuclear safety, safeguards and security.

2.2.5. Expected impacts of the changes proposed by the future Euratom programme

Implementation of the Euratom programme 2021-25 with the proposed changes will continue delivering impacts in the main research fields as indicated for the baseline scenario (see Table 6). The modifications will bring additional impacts in specific fields as indicated in Table 10 Some changes concerning horizontal aspects of the programme such as education, training and infrastructures will further improve impacts in the main research fields.

Table 10 — Expected impacts of the changes to the future programme

Field	Expected impacts
Nuclear science and ionising radiation applications	- Support implementation of the 2018 EU strategy for nuclear science and radiation technology applications (under preparation by DG Energy) - Support standardisation of health practices involving radiation (reduction of doses for patients and healthcare workforce, etc.) - Introduce innovative applications of radiation in medical sector - Support the development of centres of excellence in medical isotopes research - Use Euratom programme's actions in nuclear infrastructures to support EU efforts on the supply of medical isotopes (Mo-99, Tc-99) - Further develop medical applications by resolving issues concerning radioactive waste in the medical sector - Support the sector via Euratom-funded actions in education and training - Deliver up-to-date data on the research sector in the field (staff, students, etc.)
Education and training **Knowledge management**	- Support PhD students working on subjects related to the fusion roadmap - Increase the number of researchers and engineers receiving support from the 210 target for 2014-2020 - Support 10 MSCA fellows per year on fusion topics - Evolve education and training support for the CDA/EDA of DEMO by targeting engineering needs especially as regards nuclear skills - Guarantee sources of new talent with support for internships, mobility access to infrastructures, etc. - Support all PhD students working on subjects related to the EJPs in radiation protection and waste management - Deliver different forms of support (mobility, MSCAs, access to infrastructures) to most students of fission (BSc, PhD, Masters) in the nuclear field in the EU (estimate) The JRC will further develop knowledge management tools in several fields related to nuclear safety, waste management, safeguards or nuclear security. These will include communities of practice, users networks, etc.
Decom-missioning	Implement the decommissioning roadmap established by Euratom project funded under WP 2018 Provide programme support for sharing of best practices and new solutions applied to all decommissioning projects launched by EC since early 90s Contribute towards safety improvements, time shortening and cost reduction of dismantling, decommissioning and environmental remediation activities

Fusion energy	Provide fusion power plant relevant high-power component technology Provide facilities for fusion-relevant materials testing. Ensure science-technology and gender balance in human resources Increase industry involvement in research activities with the subsequent completion of the DEMO conceptual design Engage in more productive international collaboration Undertake a more proactive technology transfer programme with greater associated benefits
Research infrastructures	Implement strategy for networking of research reactors in EU Open access to JRC infrastructures to improve the quality and impact of collaborative projects and training
Waste management	Improve management and transfer of knowledge and skills between generations and across national programmes over next 10-15 years

3. PROGRAMME STRUCTURE AND PRIORITIES

3.1. Which actions should broadly be prioritised under Euratom programme 2021-25 to meet its specific objectives?

Based on experience from the 2014-2018 Euratom programme, the next research and training programme should maintain the overall priorities of the current programme in terms of support for fission and fusion research, as shown below (Table 11).

Table 11 — Overall priorities of Euratom Programme 2021-25			
Fission research 55 % of the programme			**Fusion research** 45 % of the programme
Nuclear safety, safeguards and security	Radioactive waste management	Radiation protection	Research for implementing fusion roadmap

Such prioritisation is justified by the fact that nuclear research remains instrumental in maintaining the highest standards of safety, security, waste management and non-proliferation, one of the objectives of the Energy Union[39]. This is followed by the priority of retaining Europe's leadership in the nuclear domain in order to reduce energy and technology dependence.

3.1.1. Fission research

In 2021-25 research for nuclear safety will remain a top priority, with particular emphasis on accident management, ageing and long-term operation strategies. Both the ageing of the European nuclear fleet and the additional safety requirements introduced by the Nuclear Safety Directive require increased efforts in developing an understanding of the degradation mechanisms of the safety-relevant components and the impact on safety overall. This would support a science-based assessment of the safety margins and allow for timely implementation of safety improvements. The predictive tools and assessment methods developed by the programme would benefit the periodic safety reviews of

[39] See Energy Union Package, COM(2015)80.

existing nuclear installations. They would also help the regulators in assessing new designs.

In line with the interim evaluation findings and stakeholder consultation, the programme will increase emphasis on education and training (E&T), knowledge management, access to infrastructures and nuclear science and radiation technology applications (see Table 12). Another aspect of the next programme that affects all fields is about guaranteeing innovation and ensuring that commercially interesting research results get to market.

Table 12 — Priorities of Euratom fission research* in 2021-2025

Priority	Field	Description of priorities
1	**Nuclear safety**	Research on safety to accompany the safe long-term operation of the ageing European nuclear fleet. Research supporting compatibility of current and future systems with the requirements of the amended Nuclear Safety Directive
2	**Nuclear security and safeguards**	Development of modern nuclear safeguards based on different types of information, trade analysis and multidisciplinary approach. Further development of nuclear detection and forensics and capacity building support
3	**Nuclear standards**	Provision of nuclear reference materials, standards and measurements to obtain appropriate and comparable scientific results in every nuclear field. Further development of codes and standards for nuclear safety
4	**Radioactive waste management**	Implementation of European Joint Programme in research for radioactive waste management in accordance with the SRA agreed by stakeholders and national authorities
5	**Education, training, knowledge management**	Support for: MSCA fellowships for PhD and postdoc researchers; Mobility for students and researchers; Hands-on training via E&T actions within Euratom projects; Implementation of ECVET, accreditation and certification in nuclear professions; Pan-European knowledge-sharing; Management of results of past Euratom projects; More attractive education on ionising radiation and its different applications
6	**Research support for EU policies in nuclear field**	Technical support for: monitoring the progress of implementation of the Euratom directives for waste management, nuclear safety and Basic Safety Standards; implementation of EU CBRN Action Plan (COM(2017) 610); nuclear safety outside EU borders through the implementation of the Instrument for Nuclear Safety Cooperation; EEAS on nuclear security and non-proliferation
7	**Fission research infrastructures**	Support for: availability and accessibility of key fission research infrastructures; mobility of researchers to access infrastructures; open access to JRC infrastructures
8	**Radiation protection and ionising radiation applications**	Implementation of European Joint Programme in radiation protection research integrating low dose biology, epidemiology, dosimetry, radiology, nuclear medicine, radioecology and preparedness to nuclear emergencies. Research for ionising radiation applications in medical field
9	**Research for decommissioning of nuclear installations**	Support for the development and evaluation of technologies for decommissioning and environmental remediation of nuclear facilities. Sharing best practices and knowledge on decommissioning

* direct and indirect actions combined

Should the Euratom funding during the Euratom programme 2021-25 fall below the 2014-2020 level in absolute terms, the key priority objectives would be affected. This would come at a time when nuclear regulators are frequently called on to assess the safety level of the European nuclear fleet, in the light of the new Nuclear Safety Directive, before long-term operation decisions are taken.

Maintaining the level of innovation for safety improvements will depend on the level of resources and stakeholder support, and on the increasing engagement of industry. With strong support above the critical mass — i.e. with resources equal to or greater than those provided in the 2014-18 programme — it is expected that key safety challenges for fission electricity can be appropriately anticipated. The stakeholder consultation points strongly to the need for an increased budget. The nuclear research community declares its readiness to increase its contribution in co-funding of collaborative research and innovation projects, convinced of the urgent need for a larger research portfolio at European level.

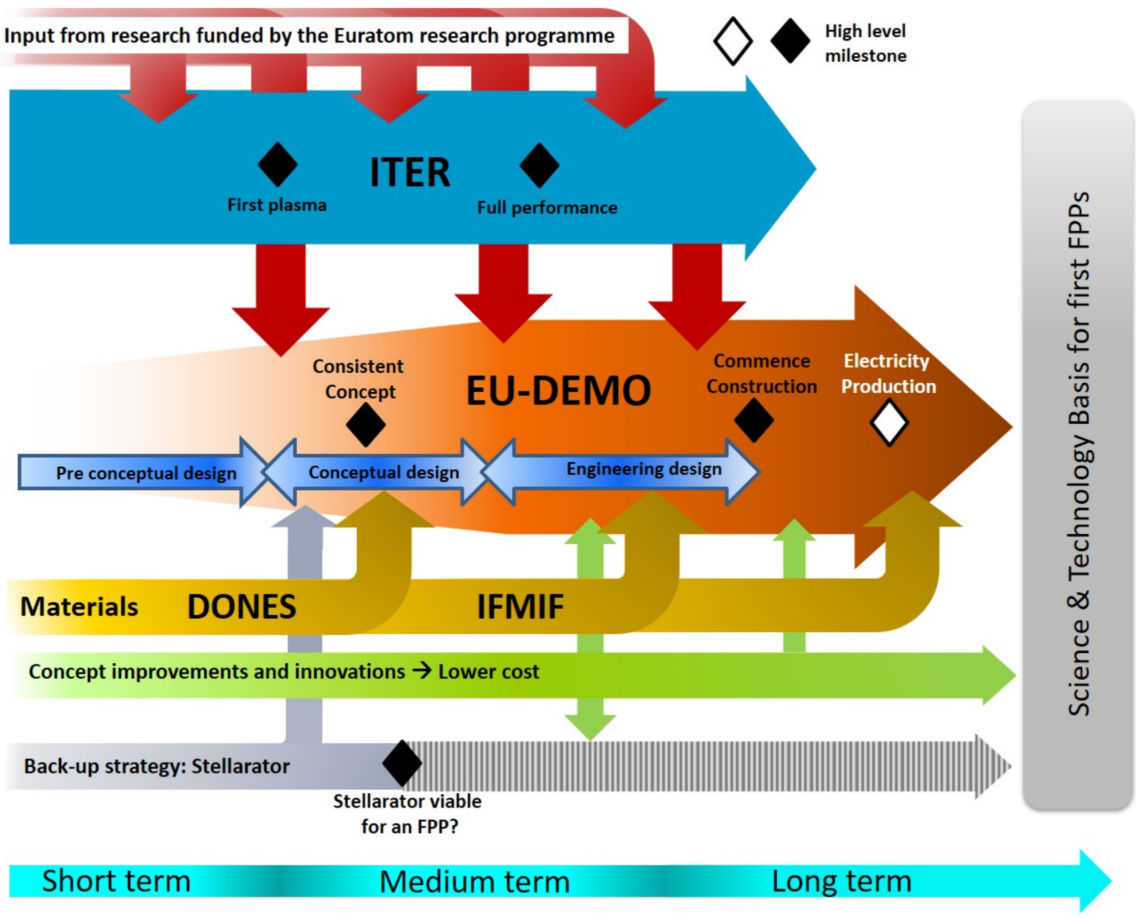
With regard to direct actions, the JRC will need to maintain its competences to comply with its mandate in nuclear safety, safeguards and security, and to support the implementation of EU policies in these areas. These competences are currently under high pressure due to staff and budget cuts under the current Programme. More than half of the JRC budget is dedicated to staff costs; therefore a reduction in the budget for direct actions below current levels will have an impact on the renewal of staff and, by extension, on the transfer of skills and knowledge. Secondly, the running costs of the JRC facilities will be also reduced, with the resulting impact on the competences and achievement of objectives.

The JRC currently deals with several aspects of nuclear safety, waste management, radiation protection, safeguards, nuclear security and nuclear standards, among other things. It is in the best interest of Europe to sustain a facility such as the JRC, where a large range of nuclear-related skills is present in-house; some of these competences will even need to be reinforced as there will be an increase in their demand.

3.1.2. Fusion research

The European Joint Programme in fusion research carried out by the named beneficiary, the EUROfusion consortium, should be continued in 2021-2025. The programme of activities should address the priorities set out in the European fusion roadmap. There are several elements in this roadmap, all of which need to be closely integrated, and are outlined below. A pictorial overview is given in Figure 4.

Figure 4 — Overview of the fusion roadmap and role of Euratom programme 2021-2025



Source: EUROfusion, modified by European Commission

Since its inception, the fusion roadmap has been the go-to document for aligning the research priorities of European laboratories and universities in the field of fusion research and development towards the ultimate goal of achieving electricity from fusion energy. Key facilities in the roadmap are: the international ITER tokamak, under construction in France, that will demonstrate the scientific feasibility of fusion as an energy source; a fusion neutron source facility for materials development and qualification (DONES); and a DEMO demonstration reactor, which will deliver hundreds of megawatts of electricity to the grid and operate with a closed fuel cycle.

This roadmap is currently being updated by the research stakeholders to take account of the revised ITER baseline[40]. However, the general strategy will remain unchanged. The adoption by the European fusion stakeholders of this first update is expected by mid-2018, following the STC review in February 2018. The objectives specified in this update will become the priorities of the Euratom programme 2021-25 as defined in Table 13. As the EUROfusion grant agreement will be the main action for implementing the fusion research activities, the programme must ensure that all the administrative and financial elements are in place to enable EUROfusion to continue in 2021-25 in an

[40] Commission Communication COM(2017) 319, EU contribution to a reformed ITER project.

efficient and effective manner. In this respect, the conditions for involving industry in the work of EUROfusion are crucial. The participation of industry will be managed through a Commission's Framework Contract providing efficient and effective access of European industry to the DEMO programme needs. Access to relevant infrastructures of both pan-European and international interest are an essential element of the programme and will be provided through operating contracts under Article 10 of the Euratom Treaty.

Table 13 — Priorities of Euratom fusion research in 2021-2025 *(main priorities highlighted, not all fusion roadmap's missions indicated)*		
Priority	**Field**	**Description of priorities**
1	**Conceptual design of demonstration power plant**	Preparation by 2025 of the conceptual design of a demonstration fusion power plant (DEMO, next step after ITER) with emphasis on involvement of European industry and use of its competencies. Closer collaboration with other international DEMO programmes (e.g. the Chinese CFETR) to address common issues identified in the European fusion roadmap.
2	**Materials research**	Intensification of materials testing programme using available facilities. Euratom programme will support preparations for the construction of a fusion materials testing facility (IFMIF-DONES), including design, licensing, site preparation, etc.
3	**Heat exhaust**	Conducting research (testing of different plasma and divertor configurations) aimed at finding technically achievable solutions for the heat exhaust in a fusion power plant with support for research infrastructures of EU relevance
4	**Preparation for ITER exploitation**	Comprehensive experimental programme in facilities of European and international relevance. Continued experimental physics and technology programmes meeting the needs of the ITER project
6	**Stellarator research**	Support for research aimed at demonstrating that the stellarator could be a possible option in addition to the tokamak for a future fusion power plant (improving understanding of stellarator physics)
7	**Education and training**	Enhance the education and training through further focusing on the human resources' needs in 2021-2030 (support for Masters, PhD and postdoc programmes, use of MSCA for fostering excellence, further development of engineering skills)

The EJP in fusion research will be carried out in full complementarity and coordination with the Euratom activities, in support to the construction of ITER and support the Broader Approach managed by DG Energy.

Fusion research relies on the use of large, expensive infrastructures and long-term commitments. A prime example is the construction and exploitation of the ITER facility which will have a lifespan of some 35 years. Should the Euratom funding during the Euratom programme 2021-25 fall below the 2014-2020 level in absolute terms, key priority objectives such as the materials development and risk mitigation experiments for ITER will not be accomplished, thus delaying important objectives and milestones in the overall implementation of the fusion roadmap.

Maintaining the level of ambition and innovation as well as the rate of progress in the implementation of the fusion roadmap will depend on the level of resources and stakeholder support, and on the increasing engagement of industry. With strong support above the critical mass — i.e. with resources equal to or greater than those provided in the 2014-2018 Euratom programme — it is expected that the first fusion electricity can be generated in Europe early in the second half of this century, thus ultimately leading to the introduction of commercial fusion power plants as part of a future sustainable energy mix.

Fusion presents a special opportunity to provide a long-term, robust supply of low-carbon electricity as part of a sustainable energy mix in Europe and worldwide. Fusion distinguishes itself from other low-carbon electricity sources in that it can be an intrinsically safe base-load electricity provider in regions and conditions where this is required, thus eliminating issues of availability of supply and location.

The fusion roadmap outlines the approach chosen by Europe to address the significant remaining scientific, engineering and industrial challenges, many of which have synergies with other science and technology fields. Europe has a leading position in the international fusion research community and has developed expertise in all relevant areas, so is well placed to implement the roadmap. Additionally, Europe is currently developing the necessary industrial expertise to be able to take full advantage of this leadership in terms of know-how, spin-offs and jobs if suitably sustained. Fusion is an international endeavour as exemplified by ITER, and Europe will continue to engage strongly with its international partners.

3.2. Subsidiarity (EU added value/necessity for EU action) and proportionality dimensions of the Euratom programme

The future Euratom programme will be based on Articles 4 and 7 of the Euratom Treaty. According to Article 4 the Commission is responsible for promoting and facilitating nuclear research in the Member States, and for complementing it by carrying out a Community research and training programme. Such programmes are adopted by the Council, acting unanimously on a proposal from the Commission (Article 7 of the Treaty). In addition, Article 8 of the Treaty establishes the Joint Research Centre for implementing research and other tasks, including introducing uniform nuclear terminology and a standard system of measurements.

This proposal is an initiative in an area of shared competence and, therefore, the necessity and EU added value tests of the subsidiarity principle apply.

The European added value of nuclear research is made explicit in the Euratom Treaty itself and the Commission has an obligation to put forward an R&D programme to complement those in Member States. The justification for Euratom intervention is based mainly on the need to ensure high and uniform levels of nuclear safety in Europe. Moreover, in chapter 3 on health and safety, the Treaty also establishes the obligation for Member States to establish provisions on basic safety standards and to monitor the level of radioactivity in the environment on their territory. Through the JRC, the Commission provides standards and technical means to ensure that Member States fulfil their obligations properly.

The Commission, in accordance with the chapter 7 of the Treaty, must fulfil its safeguarding obligations, in particular safeguarding the existing radioactive materials in the EU and the obligations assumed under the non-proliferation treaty. Under the Euratom research and training programme the JRC develops methods, standards and techniques and provides scientific and technical support to other Commission departments.

The feedback from research stakeholders and end-users of nuclear research such as nuclear regulators, NPP operators, industry and radiation protection authorities[41] shows that the current programme respects the subsidiarity and proportionality principles (see Table 14). Given the similar features and scope, these findings can be extended to the future Euratom programme 2021-2025.

The Euratom programme's intervention does not replace national R&I actions and does not go beyond what is required to achieve the objectives of the Union. Member States will continue investing in their national research programmes to address specific issues concerning nuclear safety and radiation protection.

Table 14 — Stakeholders and end-users' views on the EU added value of the Euratom programme (2017 open public consultation) *(% of 'agree' and 'tend to agree' answers)*	
Programme is improving knowledge-sharing and information dissemination	89 %
Programme is mobilising a wider pool of high-level, multidisciplinary skills than is available at national level	85 %
Euratom is undertaking programmes beyond the reach of individual Member States so that objectives that could not otherwise be achieved can be met	82 %

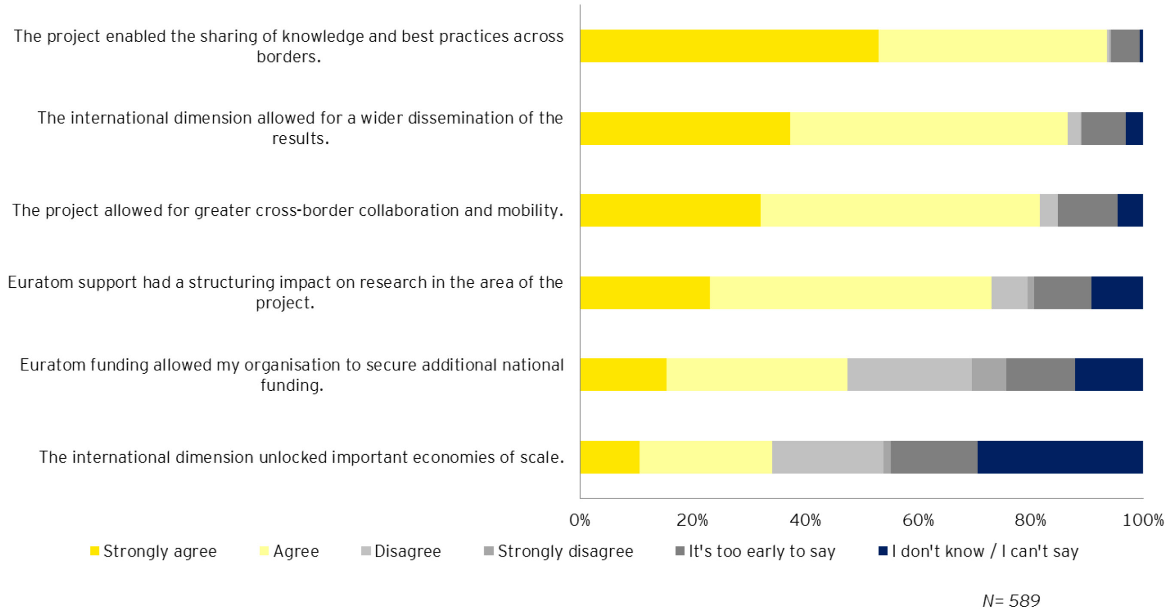
Source: European Commission

The main messages from the 2017 public consultation are also confirmed by the results of the survey carried out by Ernst & Young[42] to gauge in more detail the added value provided by Euratom research projects, compared to research conducted at national level or on the basis of bilateral international agreements. The respondents were presented with the opportunity to provide their opinion on several aspects of added value (see Figure 5). The main types of European added value underlined by the respondents are better sharing of knowledge and best practices across borders, the wider dissemination of results allowed by international dimension, greater cross-border collaboration and mobility, and the contribution to the structuring of research. However, the Euratom programme is not seen as exerting a strong influence on the financial aspects of the projects: only 34 % of the respondents agree that the European project provides significant economies of scale and a little under half feel that Euratom funding allows their organisation to secure additional national funding.

41 In all, 63 % respondents to the 2017 consultation said that they were 'end-users' of Euratom-funded research.

42 A total of 589 replies were received from Euratom project coordinators or members of project consortia launched between 2007 and 2015. For more details see Ernst & Young study 2016.

Figure 5 — Main types of EU added value of the Euratom programme identified by the respondents to the E&Y survey



Source: Ernst & Young study

Some respondents also underlined other types of added value. The European programme brings some important nuclear research issues to the European Commission's attention and enhances the creation of a common vision of research challenges across European organisations. European action is also considered as key in training the next generation of nuclear specialists, through cooperation between educational organisations and with nuclear companies.

This picture of the added value of the Euratom programme is similar to the overview of different aspects of the added value of EU-funded research explained in the Impact Assessment for the Horizon Europe Framework Programme for Research and Innovation. This is especially true as regards strengthening scientific excellence, creating a critical mass of resources to address challenges and building multidisciplinary transnational networks for more impact.

4. Delivery mechanisms

4.1. Main mechanisms to deliver funding under Euratom programme 2021-25

The Euratom programme complements the Horizon Europe Framework Programme's nuclear research activities and shares the same rules for participation. For this reason, the main features of the delivery mechanism for the Euratom programme 2021-2025 will also be shared with the EU Framework Programme (see Box 1).

Box 1 — Delivery mechanism shared with the Horizon Europe Framework Programme for Research and Innovation	
- Strategic programming process	- Forms of grants
- Single set of rules for participation	- Proposal evaluation and selection
- Calls for proposals	- Project management
- Funding model	- Dissemination and exploitation

For more details on these features and how they will help achieve the MFF's cross-cutting objectives (simplification, flexibility, coherence, synergies and focus on performance), please refer to the impact assessment for the Horizon Europe Framework Programme.

Taking into account the specifics of the Euratom programme (such as the importance of EJPs, the role of industry and research infrastructures, and the minor role of SMEs), along with the findings of the 2014-2018 Euratom programme's interim evaluation, some areas for improving delivery mechanisms must be carefully considered post-2020. This is true, in particular, for those areas that will have a strong impact on the cross-cutting objectives of the future MFF:

a) Cross-cutting actions with Horizon Europe Framework Programme

Implementation of some specific objectives of the future Euratom programme may require cross-cutting actions with the Horizon Europe Framework Programme. This may include:

- the specific objective of the Euratom programme 2021-2025 concerning applications of ionising radiation (see section 2.2), which requires cross-cutting actions with the Horizon Europe Framework Programme (health part). Such actions, for example in medical applications of radiation (e.g. brachytherapy[43]), may make it possible to address challenging medical and radiation protection aspects at the same time; and
- the specific objective on education and training, which requires cross-cutting actions with the MSCAs in order to make nuclear researchers eligible for MSCA fellowships.

Experience of Horizon 2020 shows that to launch and implement such actions effectively, the following conditions must be met:

- both the legal acts establishing the Euratom and EU research programmes should contain provisions facilitating the establishment of cross-cutting actions;
- these provisions should in particular address issues around the joint financing of such actions and appropriate decision-making involving different programme committees;
- similarly, legal provisions should facilitate the use of the FP's instruments such as MSCAs with financial contribution from the Euratom programme.

b) Improvements in the use of European Joint Programmes (EJPs) by the Euratom Programme

Under the 2014-2018 Euratom programme, the Euratom funding for EJPs in fission and fusion research accounted for almost a third of the programme's total budget. It is

[43] Treatment for cancer involving inserting radioactive implants directly into the tissue.

expected that EJPs established in these areas will continue to play a significant role under the future programme, under specific conditions (see Box 2).

Box 2 — conditions for continuation of funding for EJPs in nuclear research	
- Alignment with priorities of the Euratom programme - Positive evaluation by independent experts following an open call for proposals (fission) and a named beneficiary (fusion) - Up-to-date joint strategic research agenda or research roadmap agreed by EJP members with research topics assigned priority on the basis of actual scientific and societal challenges - Open access for all research teams on the basis of scientific excellence	- Implementation of the best practices for internal organisation of EJP consortium - Involvement of all interested EU Member States or associated countries - EJP duration of up to 5 years, with possible extension for another two years, if the Euratom programme 2021-2025 is extended - Level of Euratom funding close to 50 %

As the rules for participation will set only some general principles for the future partnerships, which include EJPs, it is important to ensure that implementing provisions such as Commission decisions on the model grant agreement and on the work programmes address some issues raised by the interim evaluation[44] and by research stakeholders during the consultation.

The first recommendation referred to the inclusiveness of the European joint programme. The expert group pointed out that even if the level of excellence remains the key for applying for research funding, emerging contributors with the potential to provide new ideas and innovation, should be able to continue and be further encouraged to participate in the joint programme. During the 2014-18 implementation of the fusion programme, this was done via the option of involving different entities as linked third parties. However, this solution was not always adequate, especially for the involvement of industry, because of the requirement to demonstrate the existence of a past legal link with one of the beneficiaries. This requirement was not always fulfilled, resulting in an inability to involve certain industries in the programme as third parties. This weakness of the EJP as regards involving industry was also underlined by the Fusion Industry Innovation Forum (FIIF) and the EUROfusion consortium in their position papers submitted during the stakeholder consultation.

To address this problem it will be necessary to revise the conditions for linked third parties participating in the European Joint Programmes (in fission and fusion research). In particular, entities with no previous link to a beneficiary must be able to become third parties where research cooperation is deemed important. Furthermore, to boost industry involvement in the EU fusion programme, it is desirable to have the option of utilising framework contracts between industrial entities and beneficiaries to provide services to and/or framework partnerships with the consortium. In addition, experience shows that, in many cases, the current rules on depreciation of hardware in the grant agreement impede the procurement of components needed by the joint programme. The next Euratom programme might therefore consider reimbursing the cost of the equipment. Also, it would be beneficial for industry involvement to allow for pre-commercial procurement.

44 Commission Staff Working Document SWD(2017) 427.

Another recommendation from the group of independent experts for the organisation of the European fusion joint programme, and particularly for the fusion EJP, was to review the system of unit costs. This system has been used for the mobility of researchers and secondment of staff, but has in practice been found not to be well adapted to the evolving needs of EUROfusion. The EUROfusion consortium also raised this point during the stakeholder consultation. A complicating factor in this context is the significant difference in salaries between researchers in the EU-12 Member States and the rest of the European Union. Furthermore, seconded staff with children face additional problems with costs for schools etc. To make it easier to second staff (from all the Member States) to vital functions within EUROfusion, and to improve mobility for researchers, it will be necessary to revise the current system of unit costs. This could be achieved in three ways: firstly, by introducing a ceiling on unit costs for short-term mobility; secondly, by updating the unit costs for education allowances for children so as not to discriminate against researchers with families; and thirdly by extending the use of unit costs for long-term secondments to third countries with which the Euratom fusion programme has specific international collaboration, for instance for European exploitation of the Japanese JT-60SA tokamak.

Concerning better project management within EUROfusion, the group of independent experts suggested firmer arrangements for EUROfusion project management and making the programme manager responsible for the development and implementation strategy. To follow up on this recommendation, it is proposed that the EJP under the Euratom programme 2021-25 should provide a training package on project management. Likewise, following the recommendation from the FIIF in its position paper, the introduction of a Full Lifecycle Cost management (FLCM) method for the estimation the costs of a DEMO could be envisaged.

As demonstrated in the above paragraphs, the operational experience and consultation with the main stakeholders in fusion research has highlighted many areas where improvements are desirable. Consequently, in preparing the implementing provisions for the future Euratom programme these will all be taken into account to ensure effective implementation of the EJPs.

c) Synergies with EU cohesion and structural funds

In 2011 the European Commission approved European Regional Development Fund (ERDF)[45] support funding of EUR 5.5 million for the construction of a new research facility in Řež in the Czech Republic, which now hosts helium and supercritical water research loops. Early 2014, the Czech Republic obtained a further EUR 85 million in ERDF funding (bringing the total to EUR 100 million) for their SUStainable ENergy project (SUSEN). Building such a research infrastructure extends their energy research possibilities, the emphasis being on nuclear technologies at the Řež Research Centre and Pilsen University of West Bohemia. It also allows them to act as a relevant research partner within the Commission's smart specialisation platforms for energy cooperation, involving the establishment of partnerships and cooperation with other European research centres. All Member States and regions should remain eligible for support from the ERDF, the European Social Fund and the Cohesion Fund to support them in building their research capacity.

[45] For more on the ERDF, see http://ec.europa.eu/regional_policy/en/funding/erdf/.

d) Funding model

The rules for participation, shared with Horizon Europe Framework Programme, will maintain the single reimbursement rate (up to 100 % of eligible costs for Research and Innovation Actions and up to 70 % for Innovation Actions). It will be possible to reduce the funding rate for implementing specific actions, where duly justified in the Euratom work programmes, in particular for research topics involving industry. A flexible funding rate could apply to funding for third parties involved in the EJPs.

5. HOW WILL PERFORMANCE BE MONITORED AND EVALUATED?

5.1. Lessons learned from monitoring and evaluation of Euratom Research and Training Programme 2014-2018

In 2014-2018 the Euratom programme shared its monitoring and the evaluation system with the Horizon 2020 Framework Programme for Research and Innovation. As with the latter, the Euratom programme marked a shift in performance measurement, with a set of key performance indicators defined in its legal basis. While the future Euratom programme can usefully take up some of these indicators, the interim evaluation pointed to the need for a more integrated approach to assess the impacts of the whole programme, including direct and indirect actions. Learning from experience, the performance of the future programme will be subject to a single evaluation, monitoring the progress that programme as a whole has made towards its common specific objectives.

In line with changes proposed for the Horizon Europe, it is therefore proposed that performance indicators, to the extent possible, are developed for the entire programme, given the common objectives and interlinkages between the direct and indirect actions. Nevertheless, to define meaningful indicators, it is necessary to keep in mind the specific characteristics of both the direct and indirect actions of the programme and the different way of implementing them to meet the common objectives, and to consider the parts of the programme exclusively dealt with by direct actions.

The selected indicators should allow for a clear attribution of the effects observed to the Euratom programme. The performance framework will also distinguish between progress indicators in the short, medium and long term according to key impacts. With the aim of further simplifying and reducing the administrative burden for participants in indirect actions, better use will be made of existing indicators (e.g. indicators and data used by other EU or national programmes or other external databases), of additional information providers other than beneficiaries (such as project evaluators or reviewers) and of new ICT tools (e.g. standardised IT identifiers of researchers and companies). More automated data collection systems will also make for continued data collection after the project ends, without burdening beneficiaries. The performance framework will be simple and easy to communicate, with a limited number of indicators that a wider audience can understand, and better dissemination and reporting activities.

5.2. Future monitoring and evaluation arrangements

Prior to the 2021-25 Euratom programme’s launch, the baseline data for all performance indicators, mainly on the 2014-2020 programme, will be completed to allow for benchmarking and assessing progress over time.

The future monitoring and evaluation arrangements for the Euratom programme will be shared with the Horizon Europe Framework Programme for Research and Innovation. Implementation data will be available on a dedicated online portal. Every year, the Commission will publish a report analysing progress on key dimensions of the Framework Programme's and Euratom programme's implementation. Monitoring arrangements will be put in place to provide an analysis of the effects of the programme. This will include the use of unique identifiers for researchers and companies, allowing for the development of control groups. The monitoring system will be one of the key sources of information for evaluations of the future programme. The CORDA system implemented by the RTD Common Support Centre will continue to be the key repository of monitoring data, as under previous programmes.

Evaluations will provide a robust evidence-based judgment of the performance of the programme based on a wide set of quantitative and qualitative data sources and analytical methods. Evaluations will be based on the Commission's internal evaluation capacities with the assistance of external contractors or experts. Results from the evaluations will be communicated formally to the other institutions and to the stakeholder community at large, to allow for a broad debate on the issues addressed.

In preparation for the launch of the future programme, an evaluation and monitoring strategy will be developed. This strategy will ensure appropriate and systematic evaluation coverage of the whole programme, with a detailed timetable for specific evaluation work.

- An interim evaluation will be performed no later than 2023 (3 years into the programme[46]), according to the evaluation criteria of relevance, coherence, efficiency, effectiveness and EU added value. This evaluation will rely on reports from an independent expert group and the contractors' evaluation of the specific aspects of the programme. It will also provide a comprehensive overview of the state of implementation and report on the longer-term effects of 2014-2020 Euratom programme. The short-term recommendations for improvements from the interim evaluation will feed into implementation and management over the remaining years of the programme and into preparations for its extension to 2026-27[47]. The longer-term recommendations will serve as inputs for the debate on the future Euratom research and training programmes, and will contribute substantially to future *ex-ante* impact assessments.
- An ex-post evaluation will be carried out in 2029 (two years after the end of the programme) with the same evaluation criteria. It will rely on in-depth evaluations of each area of the programme (fusion energy, nuclear safety, waste management, radiation protection, nuclear security and safeguards), using the same criteria and common templates. It will be prepared starting in 2027 through the performance of a set of dedicated studies.

Networking across the Commission departments involved in the implementation of the Euratom programme, in particular DG Research, the Joint Research Centre and DG Energy is essential to ensure an efficient and coherent evaluation and monitoring. It is

[46] In accordance with Article 7 of the Euratom Treaty, a Community research programme can be no longer than 5 years in length.

[47] An extension is necessary to match the duration of the MFF and Horizon Europe Framework Programme for Research and Innovation.

equally important to step up the efforts to connect with the programme's research stakeholders and end-users. The Commission will ensure that appropriate feedback is gathered via surveys, seminars and workshops.

To ensure full transparency in relation to the programme's performance, a dedicated evaluation and monitoring website for the future Euratom programme and Horizon Europe Framework Programme will present all relevant material and studies performed, following up on the website set up for current Euratom Programme and Horizon 2020.

5.3. Impact indicators

Progress towards achieving the specific objectives of the Euratom programme will be measured using four impact categories using indicators shared with Framework Programme for Research and Innovation[48].

a) **Scientific impacts -** the programme is expected to make progress as regards knowledge for reinforcing nuclear safety and security; safe applications of ionising radiation, spent fuel and radioactive waste management; radiation protection; and the development of fusion energy. Progress in this area will be measured by indicators concerning scientific publications, progress in the implementation of the fusion roadmap, development of expertise and skills, access to research infrastructures.

<table>
<tr><th>Programme's objective</th><th>Short-term indicators (outputs)</th><th>Medium-term indicators (results)</th><th>Longer-term</th></tr>
<tr><td rowspan="2">Improving the safe and secure use of nuclear energy and non-power applications of ionizing radiation, including nuclear safety, security, safeguards, radiation protection, safe spent fuel, radioactive waste management and decommissioning.</td><td>Publications –
number of Euratom peer-reviewed scientific publications</td><td>Citations -
Field-Weighted Citation Index of Euratom peer-reviewed scientific publications</td><td>World-class science -
Number and share of peer reviewed publications from Euratom programme that are core contribution to scientific fields</td></tr>
<tr><td>Shared knowledge -
Share of research outputs (open data/ publication/ software etc.) shared through open knowledge infrastructures</td><td>Knowledge diffusion -
Share of open access research outputs actively used/cited</td><td>New collaborations -
Share of Euratom beneficiaries having developed new transdisciplinary/ trans-sectoral collaborations with users of their open Euratom R&I outputs</td></tr>
<tr><td>Fostering the development of fusion energy</td><td colspan="3">Progress in the implementation of the fusion roadmap –
Percentage of the fusion roadmap's milestones established for the period 2021-2025 reached by the Euratom programme</td></tr>
<tr><td rowspan="2">Maintaining and further developing expertise and excellence in the Union</td><td>Skills -
Number of researchers having benefitted from upskilling activities of the Euratom programme (through training, mobility and access to infrastructures)</td><td>Careers -
Number and share of upskilled researchers with more influence in their R&I field</td><td>Working conditions -
Number and share of upskilled researchers with improved working conditions</td></tr>
<tr><td colspan="3">The number of researchers having access to research infrastructures through the programme support</td></tr>
</table>

48 Unless stated otherwise methodology and data collection will be shared with Horizon Europe Framework Programme for Research and Innovation.

	Reference materials delivered and reference measurements incorporated to a library	Number of international standards modified

b) **Societal impacts** – the programme helps addressing EU policy priorities concerning nuclear safety and security, radiation protection and ionising radiation applications through research and innovation, as shown by the portfolios of projects generating outputs contributing to tackling challenges in these fields. Societal impact is also measured in terms of the developments in the field of nuclear security and safeguards.

Programme's objective	**Short-term indicators (outputs)**	**Medium-term indicators (results)**	**Longer-term**
Improving the safe and secure use of nuclear energy and non-power applications of ionizing radiation, including nuclear safety, security, safeguards, radiation protection, safe spent fuel, radioactive waste management and decommissioning	Outputs - Number and share of outputs aimed at addressing specific EU policy priorities	Solutions - Number and share of innovations and scientific results addressing specific EU policy priorities	Benefits - Aggregated estimated effects from use of Euratom-funded results, on tackling specific EU policy priorities, including contribution to the policy and law-making cycle
	Number of services delivered in support of safeguards in EU	Number of technical systems provided and in use	
	Number of training sessions delivered to front-line officers		

c) **Innovation impacts -** the programme is expected to deliver innovation impacts supporting delivery of its specific objectives. Progress in this area will be measured by indicators concerning intellectual property rights (IPR), innovative products, methods and processes and their use, along with job creation.

Programme's objective	**Short-term indicators (outputs)**	**Medium-term indicators (results)**	**Longer-term**
Maintaining and further developing expertise and excellence in the Union	Innovative outputs - Number of innovative products, processes or methods from Euratom programme (by type of innovation) and Intellectual Property Rights (IPR) applications	Innovations - Number of innovations from the Euratom programme (by type of innovation) including from awarded IPRs	Economic growth - Creation, growth and market shares of companies having developed Euratom funded innovations
	Supported employment - Number of FTE jobs created and jobs maintained in beneficiary entities for the Euratom project (by type of job)	Sustained employment - Increase of FTE jobs in beneficiary entities following Euratom project (by type of job)	Total employment - Number of direct and indirect jobs created or maintained due to diffusion of Euratom results (by type of job)
	Amount of public and private investment mobilised with the initial Euratom investment	Amount of public and private investment mobilised to exploit or scale up Euratom results	EU progress towards 3 % GDP target due to Euratom programme

d) **Policy impact.** The Euratom programme provides scientific evidence for policy-making. This in particular concerns scientific support for other Commission services, such as the support to Euratom safeguards, or to the implementation by Member States of nuclear and ionising radiation-related directives[49].

Programme's objective	Short-term indicators (outputs)	Medium-term indicators (results)	Longer-term
Supporting Union policy on nuclear safety, safeguards and security	Policy-relevant findings - Number of Euratom projects producing policy-relevant findings	Policy maker engagement Number of Euratom outputs having a demonstrable impact on the EU policy	Policy uptake Number and share of Euratom projects findings cited in policy/programmatic documents

Targets will be defined for both indirect and direct actions to reflect the expected results for each part of the programme.

The indicators are complemented by a set of key management indicators to gauge implementation of the programme and monitor the related JRC performance (collaborative partnerships, support for international organisations and participation in JRC-managed networks).Key management and implementation data will be collected for:

- *Number of proposals and applications submitted, EC contribution requested and total costs of submitted proposals (by source of funds)*
- *Number of proposals reaching the quality threshold*
- *Number of retained proposals*
- *Success rates of proposals*
- *EC contribution and total costs of retained proposals (by source of funds)*
- *Number of participations and single participants*
- *Number of collaborative projects where JRC participates*
- *Number of participants and countries in JRC networks*
- *Number of collaborations with international organisations* (IAEA, OECD-NEA, standardisation, etc.)

This information shall be collected according to:

- *Types of action*
- *Types of organisations, including Civil Society Organisations (with specific data for SMEs)*
- *Countries of applicants and participants (including from associated and third countries)*
- *Sectors*
- *Disciplines*

Data shall also be monitored on the profiles of beneficiaries and evaluators:

[49] Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations; 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 Commission Regulation (Euratom) No 302/2005 of 8 February 2005 on the application of Euratom safeguards.

- *Gender balance (in projects, in EC advisory groups and evaluators)*
- *Role(s) in project*
- *Share of newcomers to the Programme*

Data shall also be monitored on the implementation processes:

- *Time-to-grant*
- *Time-to-pay*
- *Error rate*
- *Satisfaction rate*
- *Rate of risk taking*

Data shall also be monitored on:

- *The financial contribution that is climate-related*
- *The financial contribution that is sustainability-related*

Data shall also be collected on:

- *Dissemination of R&I results*
- *Exploitation of R&I results*
- *Exploitation and deployment of R&I results*

Annex 1: Procedural information

1. Lead DG(s), DeCIDE Planning/CWP references

Lead DG: Directorate-General for Research and Innovation (RTD)

Agenda planning number: PLAN/2017/671

2. Organisation and timing

An inter-service steering group (ISSG) on the Euratom research and training programme was set up in 2016. The ISSG is composed of representatives from four Commission Directorates-General (RTD, ENER, JRC, SG). In accordance with the Better Regulation Guidance, the ISSG was involved in drafting an interim evaluation of the Euratom programme 2014-18 and a proposal for the extension of this programme until 2020. Work on input for the impact assessment for the Euratom programme 2021-2025 began during the fourth quarter of 2017. The work was coordinated by the Strategy Unit (G.1) in the Energy Directorate of the Commission's Directorate-General for Research and Innovation (DG RTD).

3. Consultation of the RSB

The Regulatory Scrutiny Board (RSB) received a draft impact assessment report in March 2018. The RSB's opinion was adopted on 13 April 2018.

4. Evidence, sources and quality

The impact assessment is based on a wide range of sources. These include:

- internal Commission assessments;
- the input and results from the interim evaluation of the Euratom programme 2014-2018 (external expert group report)[50] and from the Commission's report (COM(2017) 697) and Staff Working Documents (SWD(2017) 426 and 427);
- the Ernst & Young study on fission and fusion research; and
- the ex-post evaluation of the Euratom 7th Framework Programme (FP7, 2007-2013)[51].

Further evidence was provided by research stakeholders in the consultation carried out in January and February 2018 (for details see Annex 2). The impact assessment's quality was ensured through a peer review of the report by units from DG RTD, JRC and DG ENER.

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50 https://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/panel_report_on_indirect_actions_of_euratom_interim_evaluation_2014-2018.pdf.

51 Annex to COM(2016) 5 and report from independent experts, https://ec.europa.eu/research/evaluations/pdf/archive/fp7-ex-post_evaluation/ki0115936enn.pdf.

Annex 2: Stakeholder consultation

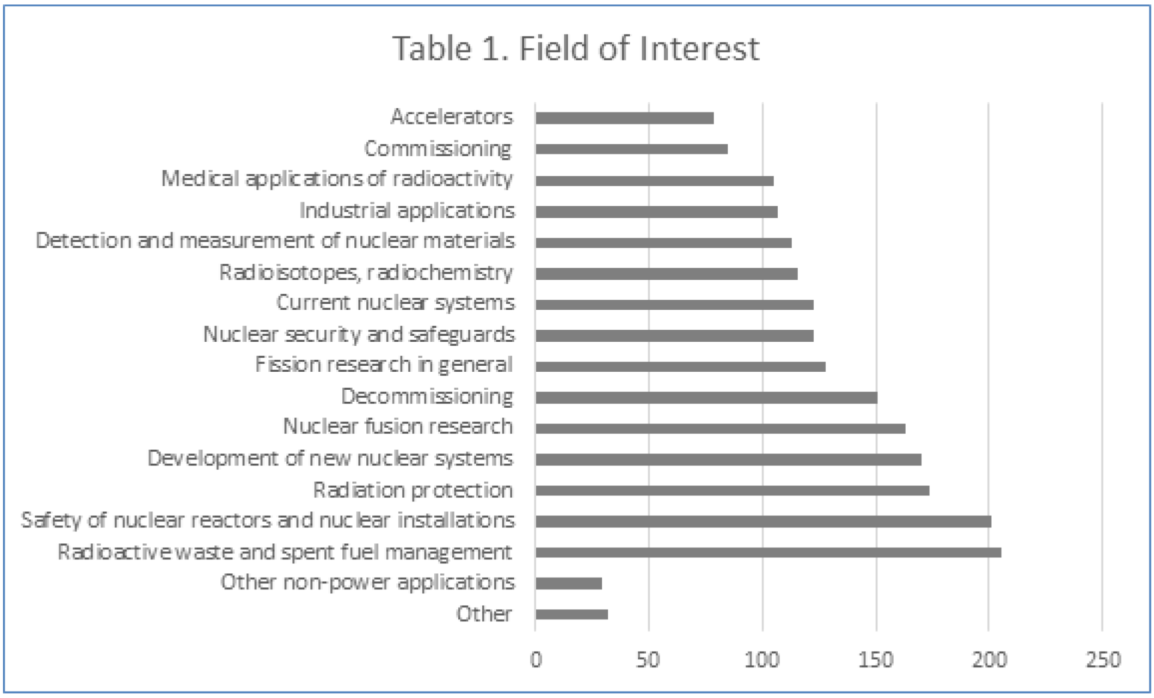
As part of the *ex-ante* impact assessment of the future Euratom Research and Training programme (2021-2025), a targeted consultation, primarily aimed at stakeholders in nuclear research, was carried out. The consultation consisted of three elements: a survey, a seminar and contributions in the form of position papers.

1. Stakeholder survey

An online questionnaire was open for replies from 22 January to 16 February 2018[52]. As targeted consultations are not published on the Commission's page for open public consultations, use was made of the *EU Survey* tool. Euratom research stakeholders were invited to participate. While the nuclear research community was the primary target audience, the survey was public, with a link provided from the Euratom research webpage.

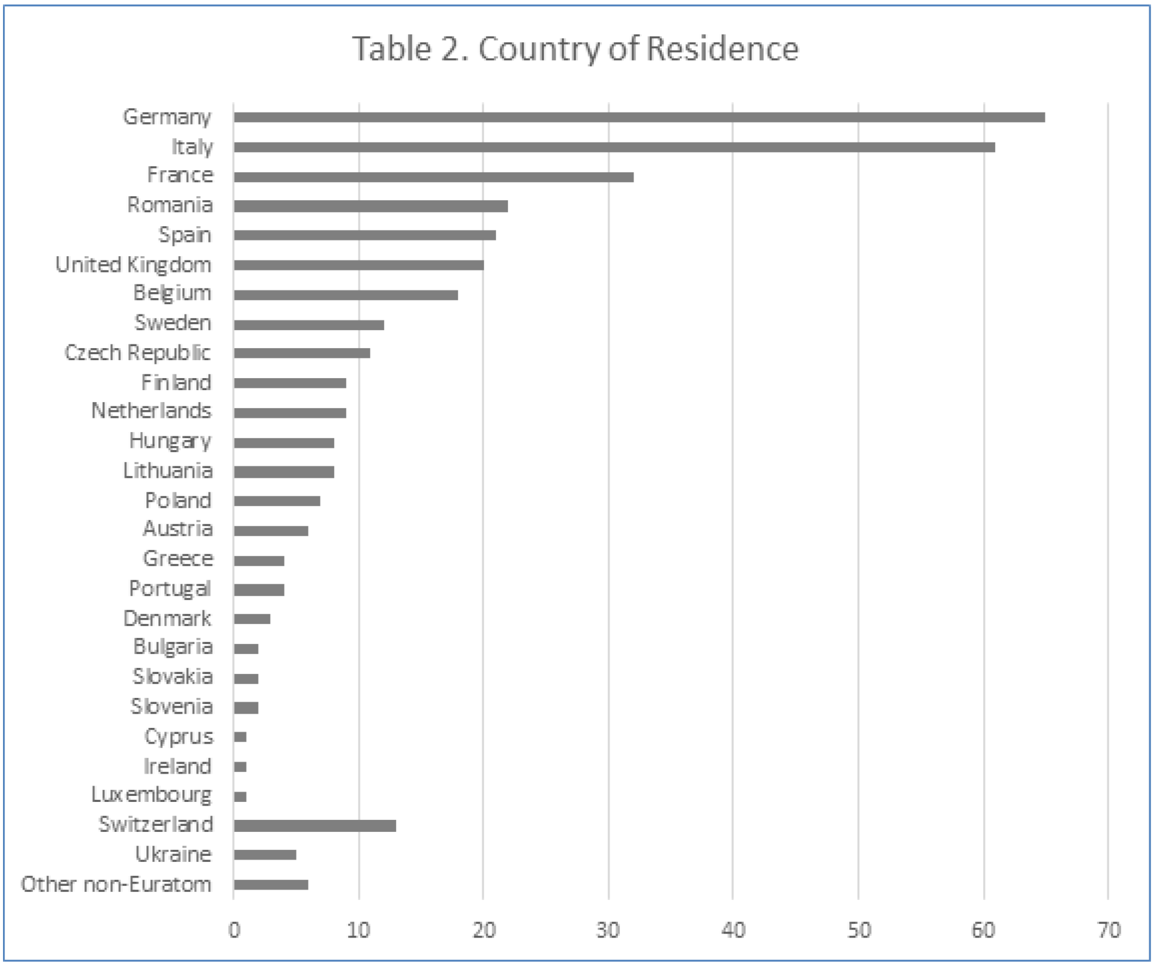
1.1. Respondents' profile

In all, 366 people answered the questionnaire, which compares favourably with the total of 323 who participated in the consultation on the interim evaluation of the 2014-2018 programme. More than half (56.1 %) said they were answering 'in a professional capacity or on behalf of an organisation', the latter including universities (13.0 %), laboratories (12.5 %) and technical support organisations (7.4 %). The fields of interest[53] and countries of residence of respondents are shown in tables 1 and 2 respectively.



52 Targeted consultations are not bound by the same minimum duration requirements as open public consultations. A period of four weeks was considered sufficient for this particular survey.

53 Respondents were allowed to indicate more than one field.



1.2. Importance of the present programme

Respondents were asked to rank the programme's actions in relation to their field of interest and their main reasons for taking part in Euratom projects. The results are shown in tables 3 and 4 below[54].

Table 3. Preferred Euratom programme actions for addressing field of interest	
Rank	*Options*
1st	Provide grants for collaborative research projects
2nd	Support education and training actions
3rd	Support access to research infrastructures
4th	Support networking and preparatory actions
5th	Support mobility of researchers
6th	Support frontier/basic research

[54] For questions requiring the rank-ordering of a series of options respondents were asked to mark their preferences starting with 1 (highest preference) and continue for as many preferences they liked (2, 3, 4, etc.). Respondents were also allowed to give a preference more than once. Replies were then scored using a Borda count with the formula *t-p+1*, where *t* is the number of options and *p* the preference given for that option.

7th	Launch European joint programmes coordinating Member States' research actions
8th	Support dissemination and exploitation of research results
9th	Support innovation (bringing new services and products to market)

Table 4. Main reasons for taking part in Euratom projects	
Rank	*Options*
1st	Receiving funding for my/our research
2nd	Establishment of research networks
3rd	Access to knowledge and/or nuclear facilities not available or difficult to acquire alone at national level, development of competences
4th	Enhancing critical mass of resources to address specific issues
5th	Credibility of the results obtained in Euratom activities
6th	Industrial competitiveness

1.3. Directions for the future programme

Respondents were also asked what would happen if they were to receive no funding from the Euratom programme 2021-2025 (they were allowed to give more than one answer). The largest group (65.2 %) said that projects would only be partially implemented, followed by those who said that the project would be funded through national or private funding only (47.6 %) and that the projects would not be implemented at all (43.6 %). The response to other questions on the future direction of the programme can be found in tables 5 to 10 below.

Table 5. What should be the role of indirect actions of the Euratom programme?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree
Euratom funding should only focus on a limited number of research areas in order to maximise impacts	25.95 %	33.53 %	31.20 %	9.33 %
Euratom funding should continue to cover the research areas of the current programme	44.61 %	42.27 %	9.91 %	3.21 %
The programme should shift more resources towards addressing basic needs in education and training, mobility, access to infrastructures, knowledge management	18.26 %	36.52 %	32.75 %	12.46 %

Table 6. What should be the role of the Euratom programme with regard to the access to fission research infrastructures?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree
The Euratom programme should support access to the relevant research infrastructures in Europe	54.7 %	38.4 %	5.7 %	1.3 %
The Euratom programme should support the networking and exchange of researchers between relevant research infrastructures in Europe	38.6 %	55.5 %	5.0 %	0.9 %
The Euratom programme should better facilitate access to the Commission's research infrastructures	30.0%	54.5 %	13.8 %	1.7 %

Table 7. What should be the role of the direct actions of the Euratom programme?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree

To provide independent scientific advice in Europe	42.9 %	41.3 %	12.6 %	3.2 %
To carry out research complementing national initiatives	38.4 %	48.3 %	11.3 %	2.0 %
To provide scientific and knowledge support to EU policies	43.8 %	49.7 %	5.3 %	1.2 %
To develop a knowledge management centre for Euratom research	24.7 %	48.4 %	21.1 %	5.8 %

Table 8. How should JRC direct actions be integrated with indirect actions of the Euratom programme?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree
The JRC should continue participating in Euratom calls for fission proposals on a competitive basis and receive funding as would any other member of a consortium	14.5 %	26.8 %	42.8 %	16.0 %
The JRC should not take part on a competitive basis in Euratom calls for proposals but instead offer in-kind contributions to applicants	24.6 %	46.6 %	21.3 %	7.5 %
The JRC should play a coordinating role in knowledge management	24.4 %	55.9 %	13.0 %	6.7 %

Table 9. What should be the role of the Euratom programme with regard to decommissioning of nuclear facilities?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree
Support for decommissioning research should play an important and similar role in the Euratom programme as research in safety, waste management and radiation protection	31.5 %	25.3 %	24.0 %	19.2 %
Euratom research on decommissioning should be limited to specific issues such as development of skills and exchange of best practices	14.6 %	37.7 %	40.9 %	6.8 %
Euratom research should support financially industry efforts on decommissioning	7.1 %	17.5 %	26.6 %	48.7 %

Table 10. To what extent should the Euratom programme be involved in non-energy applications of nuclear science such as medical applications?	Strongly agree	Tend to agree	Tend to disagree	Strongly disagree
Research on nuclear science issues for non-energy applications (medical or others) should be supported by the Euratom programme	22.0 %	23.6 %	32.1 %	22.3 %
Research on nuclear science issues for non-energy applications (medical or others) should be supported by other R&D activities (e.g. health)	36.5 %	42.0 %	17.3 %	4.2 %
Research on nuclear science issues for non-energy applications (medical or others) should be supported jointly by the Euratom programme and other R&D activities	28.8 %	34.9 %	17.9 %	18.3 %

1.4. Support for innovation

A large majority of respondents (79.9 %) felt that the Euratom programme should support breakthrough innovations in their field. They were then asked to rank-order proposals for how this could be done; the results are shown in Table 11 below.

Table 11. How should the Euratom programme support innovation in your field?	
Rank	*Options*
1st	Support early-stage, science and technology research by consortia exploring novel ideas for radically new future technologies that challenge current paradigms and venture into the unknown
2nd	Support close-to-market projects of consortia of research and industry
3rd	Support the development of European design codes and standards to facilitate deployment of innovation
4th	Support prizes for breakthrough innovation
5th	Support close-to-market and scale-up projects of a single SME or of a consortium of SMEs
6th	Provide loans

When asked how the Commission should support education and training in fission in the future programme, the options were ranked as shown in Table 12 below.

Table 12. How should the Commission support education and training in fission in the future programme?	
Rank	*Options*
1st	Providing access to research infrastructures
2nd	Providing individual fellowships to postdoc researchers
3rd	Providing individual fellowships to PhD researchers
4th	Supporting short-term exchanges for staff/researchers
5th	Supporting European training networks providing PhD education
6th	Supporting European training networks providing graduate education
7th	Launching specific E&T projects
8th	Dedicating more than 5 % of its financial support for collaborative research projects to education and training actions
9th	Supporting life-long learning in specialist fields by means of (refresher) courses
10th	Supporting individual fellowships for training at the European Commission's JRC premises

1.5. Education and training in fusion

The Euratom programme supports education and training in fusion by co-financing PhD studies and EUROfusion grants for researchers and engineers. Respondents were asked to rank possible ways the Commission could support education and training in fusion research for the future Euratom programme.

The most popular reply was 'Keep existing Euratom fusion E&T programmes', followed by 'Expand the existing Euratom fusion E&T programmes' and 'Keep existing Euratom fusion E&T programmes and enhance with Marie Skłodowska Curie fellowships'.

2. STAKEHOLDER SEMINAR

On 21 February 2018 the Commission organised a seminar for research stakeholders and representatives from Member States, on ‘Euratom Nuclear Fission Research and Training — What are the new specific needs?’. The following four topics of discussion were selected: ‘Infrastructure Open Access’, along with the closely linked ‘Nuclear Education and Training’, ’Non-Power Nuclear Science Applications’ and ’Innovation in Nuclear Research’.

The seminar highlighted the importance and awareness of available research infrastructures in the EU. In the nuclear safety domain, participants recalled the need for continued know-how on safety improvements of the existing nuclear fleet and anticipation of future nuclear safety challenges. On radiation protection the benefits of bridging research activities in the medical and non-medical sectors were highlighted. On innovation and radioisotope developments the need for a broader approach to neutron-induced transmutation was suggested.

The need for innovation was emphasised to increase safety and make efficiency and competitiveness gains. Euratom was invited to facilitate ‘acceptance’ of new tools, based on new and modern technologies, and to decrease maintenance time and the time taken to build new reactors. The early involvement of the regulator was mentioned, because in the nuclear field not only the TRL counts, but the LRL (Legislation Readiness Level) as well. New technologies (with huge innovation potential) need public support to cross the valley separating research and market. P&T addresses the needs of both industry and society and ADS technology presents a very high potential for innovation.

3. POSITION PAPERS SUBMITTED BY STAKEHOLDERS

Key messages concerning fission research

- The common position of the majority of stakeholders addressed the need to support the implementation of the highest safety and radiation protection standards and the best safety practices in all parts of the nuclear operation lifecycle. Research on further nuclear safety improvements should remain a priority.
- Stakeholders highlighted the positive impact of Euratom programmes and the need for a substantial increase in future Euratom funding to amplify EU R&I impact, to maintain coherence with the ambitious Energy Union objectives, and to maintain EU leadership in nuclear fission in the future. Nuclear research should be included in the ‘Mission Innovation’ intergovernmental initiative.
- Stakeholders proposed a ranking of R&I priorities, assessing the recent outcomes of research projects and taking account of international projects to avoid effort overlaps. Stakeholders stressed the need for further integration in relevant areas of fission research and pointed to the integration and continuation of CONCERT as a way to address the challenges in radiation protection.
- High importance was given to pursuing EU infrastructure development and to support for R&I for advanced systems. Stakeholders also consider it important to promote innovation and give more resources to innovative technologies, in particular to progress in prototype development, demonstrators and innovative processes. The need for public investments was expressed by several stakeholders involved in R&I for future innovative reactor systems; Euratom was invited to continue dedicating resources to this area and support ‘acceptance’ of new tools based on modern technologies.

- Stakeholders also mentioned the importance of nuclear science and ionising radiation technology applications, mainly in the medical sector and for industrial, research and space applications.
- Fostering nuclear science as a basis for supporting standardisation is seen by several stakeholders as an important component of the new Euratom programme. Euratom support would also be beneficial in strengthening the leading role of the EU regarding implementation of nuclear regulation worldwide.
- Research on waste management should be continued through EJP instruments contributing to the development of safe, long-term solutions for the management of ultimate nuclear waste, including final geological disposal.
- Several stakeholders propose the establishment of separate R&D-funding for the decommissioning and environmental remediation of nuclear facilities as well as the development of a coherent strategic research agenda.
- All EU and European Investment Bank financial instruments should be available to the next Euratom programme. Extension of the ERIC scheme to nuclear research infrastructure should ensure the availability of research infrastructure at EU level.
- The fission research community should have access to funding for cross-cutting nuclear fission research projects via the European Research Council (ERC) programme, and to Marie Skłodowska-Curie fellowships for researchers working in nuclear energy. Possible synergies between Euratom and Horizon Europe have to be addressed.
- The next Euratom programme should also propose instruments offering support for proof of concept, technology transfer and spin-off companies.
- The development of international networks with industry involvement and public/private partnerships for the creation of an ‘open access network’ for better use of the available research reactors should also be 'supported.
- The knowledge management and development of competence in nuclear safety and radiation protection are important for the competitiveness of European industry. The Euratom programme should develop activities to promote pan-European knowledge-sharing, including the transfer of knowledge across different fields and generations.
- The European E&T landscape should be further integrated and consolidated. The Euratom programme should continue to support academic curricula and also go beyond traditional paths by combining initiatives in the nuclear and relevant medical and industrial sectors. The programme should also offer more focused and coordinated training and promote life-long learning for specialists by means of dedicated courses. Academia should be better linked/involved with industry and institutions engaged in cutting-edge research. Including E&T activities within collaborative research projects is beneficial and should be continued. Mobility should be further encouraged, within the EU but also with third countries.
- Certain stakeholders mentioned the need to address socially relevant issues with a high impact on Europeans.
- To take stakeholders views into account while preparing work programmes, the following recommendations were made:
  - looking at SRAs;
  - consulting platforms on a regular basis;
  - consulting major operators and national programmes;
  - drafting and sending out questionnaires; and
  - giving researchers the chance to express their views on an equal footing with industry.

- Greater involvement on the part of all Member States is crucial to the success of the next programme.
- The co-funding rates should be flexible and administrative rules must be simplified.
- The EJP instrument should be improved, based on the lessons learned from CONCERT and could include more amenable procedures for third-party funding.

Key messages concerning fusion research

On fusion, five position papers were submitted in response to the stakeholder consultation (one from the EUROfusion consortium, one from the Fusion Industry Innovation Forum and three from researchers).

The EUROfusion paper concentrates on adjustments to the current implementation of EUROfusion under the EJP grant agreement.

It points out that with EUROfusion and the EJP in 2014-2018 Euratom programme, the coherence and integration of the programme itself, and its focus on delivering a DEMO design, received a significant boost. Furthermore, the conclusion of different reviews (mid-term review, the Ernst & Young management review and the interim evaluation of the Euratom programme in Horizon 2020) state that EUROfusion is fit for purpose.

While ITER remains the critical research device on the road to fusion energy, it is stressed that it is not the only research infrastructure needed. In particular, a fusion-relevant neutron source should be built for qualifying materials for DEMO in a timely fashion. Currently two Member States are interested in hosting the IFMIF-DONES facility and are in touch with the relevant authorities and the Commission.

The position paper lists four issues that affect the scientific/technical implementation of the fusion programme.

1. The main concern is that the funding for fusion in the next Euratom Programme needs to be consistent with the requirements of the fusion roadmap. If the ambitious goals set by the fusion roadmap are to be fulfilled, the funding for fusion research, outside ITER, needs to increase in FP9. On the other hand, it is worth exploring further if the research burden can be shared with international partners in some areas.
2. The second point, strongly linked to the first, merely states that it is crucial for the programme in FP9, especially ITER support, to keep the current fusion devices in the EU in operation, as well as having access to JT60-SA (under construction in Japan in the framework of the Broader Approach). There is no disagreement on the need for operation of a range of devices, but an FP9 review of facilities should be carried out at some point to ensure that the existing suite of facilities is still fit for purpose, any new ones are operating as required and there is no fragmentation of the experimental programme.
3. Education and training is crucial for the future vitality of the fusion programme, and the position paper suggests that this aspect could be improved further if Euratom had access to Marie Skłodowska-Curie Actions. The Commission is already exploring this possibility.
4. The importance of finding a way of keeping the UK in the fusion programme is stressed.

Points related to the grant agreement can be summarised as follows:

- Long-term secondment of staff to vital functions, especially the EUROfusion programme unit, is a significant issue. The differing conditions in the seconded staff's home countries make the system very uneven, putting staff from the EU-12 Member States at a particular disadvantage. Furthermore, a particular problem presents itself for seconded staff with children, where school fees in many cases can make secondment economically unfeasible.
- Short-term missions supported by unit cost declarations are problematic in some Member States because of domestic rules.
- There is a need for much increased industry involvement in EUROfusion, but the current possibilities under the grant agreement are not well suited for this purpose.
- The rules on depreciation of hardware costs in the grant agreement are perceived to inhibit or complicate procurement of equipment for some of the beneficiaries. One should note that this is a wider issue than for the fusion programme alone.
- The accounting of costs for use of research infrastructures is said to be complex under the grant agreement.

Discussions between EUROfusion and the Commission on the above issues are ongoing, with a view to resolving most of them for FP9.

The position by Dr Fasoli of the Swiss Plasma Centre is a straightforward endorsement of the EUROfusion position paper.

The position of Dr Federici, EUROfusion department Head for Power Plant Physics and Technology, adds to point 1 above in stating that any slippage in the schedule of the roadmap, because of inadequate funding, risks leading to a loss of the expertise built up in the industry and in the fusion community in general in the time gap between ITER and a DEMO. Moreover, because most civilian facilities producing tritium will be retired in a few decades from now, he draws attention to the possibility of a tritium shortage if DEMO is constructed later than currently assumed (tritium is used as a fuel component in a fusion power plant).

The position of Dr Nolte is that there is currently an artificial separation between nuclear data for fission and fusion applications. He therefore suggests the nuclear data could be a subject for a cross-cutting initiative. This is a reasonable proposition and it should be studied further.

The position paper prepared by the Management Board of the Fusion Industry Innovation Forum (FIIF-MB) highlights the desired industrial contribution to the forthcoming DEMO conceptual design phase, which runs in parallel with the next Euratom Programme. Industrial participation is considered essential to successfully realise sustainable and operational fusion power plants as quickly as possible. The FIIF comments and recommendations are in line with the strategy described in the fusion roadmap and are also consistent with the views of the EUROfusion General Assembly.

The FIIF paper further highlights key technical and programmatic industrial activities for three core areas:

Core area 1: Systems engineering/project and programme support and development/technology evaluation, creation of the design platform;

Core area 2: Technology and materials joint development R&D projects;

Core area 3: Front-end engineering and design, including close ‘project management’ support.

Furthermore, a number of recommendations are made in order to facilitate industrial participation:

- A clear industry engagement and contracting strategy with attractive conditions is required. The current practice with the two-stage process for closing contracts between research units and industry is unworkable and the option of a longer-term Framework Contract (FWC) must be considered.
- To support well-defined packages of near-term industry tasks of suitable scope and continuity, there should be a phased long-term plan of increased investment in DEMO and industry involvement.
- Industry-recognised approaches for project execution, including management, risk and cost control in the programme should be adopted.
- Better involvement of industry as a driver to expand the technological direction of ‘fusion education’ should be facilitated.
- Industry should participate in the new bodies foreseen by the revised DEMO project governance.