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PART 2/2

COMMISSION STAFF WORKING DOCUMENT

EVALUATION

Ex-post evaluation of indirect actions under the Euratom Research and Training Programme 2014-2020

Accompanying the document

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

Ex-post evaluation of the Euratom Research and Training Programme 2014-2020

{COM(2024) 549 final} - {SWD(2024) 272 final}

Contents

GLOSSARY

Term or acronym	*Meaning or definition*
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 were associated to Euratom programme 2014-2020: Switzerland (since 1979) and Ukraine (since 2016)
CoA	'Contract of Association' between Euratom and the Member States (or an organisation within a State) to create a 'Euratom Association' for implementation of fusion research before 2014. These bilateral contracts were the mechanism by which Euratom provided financial support and co-ordinated the work of all the Association laboratories.
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
Direct actions	R&I activities undertaken by the Commission through its JRC.
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
EFDA	European Fusion Development Agreement (1999-2013) – a multilateral agreement between European fusion research institutions and the European Commission (which represents Euratom) to strengthen their coordination and collaboration, and to participate in collective activities in the field of nuclear fusion research. It was replaced by EUROfusion consortium.
EJP	European Joint Programme
ENEN	European Nuclear Education Network
ENSREG	European Nuclear Safety Regulators Group
ERC	European Research Council
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
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
HLW	High-level (radioactive) waste
IA	Impact assessment; innovation action
ITER	International Thermonuclear Experimental Reactor, fusion energy research facility under construction in Cadarache, France (https://www.iter.org/)
Indirect actions	R&I activities to which Euratom provides financial support and which are undertaken by participants
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
NPP	Nuclear power plant
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
RIA	Research and Innovation Action
SME	Small or medium-sized enterprise
SRA	Strategic research agenda
STC	Euratom Scientific and Technical Committee established by Art. 134 of the Euratom Treaty
Success rate	The number of proposals that are retained for funding over the number of eligible proposals
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

This Staff Working Document provides support and evidence for the Commission's report on the ex-post evaluation of indirect actions under the Euratom Research and Training Programmes 2014-2018 and 2019-2020 as required by the Regulations establishing these Programmes[1]. While these are, strictly speaking, separate Programmes, they will be considered together for the purpose of this document, and referred to as 'the Euratom Programme 2014-2020' or 'the Programme' given their identical objectives and modes of implementation.

The outcome of this evaluation will be used in the preparation and design of the proposal for the extension of the Programme for 2026-2027 and subsequent Programmes. It assesses progress in achieving the Programme's objectives, the efficiency in use of resources, its continued relevance, the coherence within the Programme and with other instruments, and its EU added value[2].

This evaluation covers 'indirect actions' of the Programme, which is research carried out by trans-European project consortia of private and public research groups. These actions address the safety of nuclear systems, waste management and radiation protection, as well as the feasibility of fusion as a power source. Euratom Programme is also implemented via 'direct actions' concerning fission research carried out by the Commission through its Joint Research Centre. According to Regulations establishing the Programme, direct and indirect actions shall be subject to separate evaluations as they have separate specific objectives and means of implementation. For the purpose of the ex-post evaluation, direct actions have been evaluated separately and are subject of a separate Staff Working Document.

1.1. Methodology for evaluating indirect actions

In line with the Council Regulations, the ex-post evaluation was carried out by the Commission with the assistance of independent experts. The evaluation started in June 2022. The exercise was based on the following data sources: [3]

- the Commission's statistics on the implementation and results of Euratom calls for proposals launched during 2014-2020
- periodic reports from EUROfusion and fission projects covering 2014-2020[4]

[1] Article 22 of Council Regulation (Euratom) No 1314/2013 of 16 December 2013 on the Research and Training Programme of the European Atomic Energy Community (2014-2018) complementing the Horizon 2020 Framework Programme for Research and Innovation (OJ L 347, 20.12.2013, p. 948) and Article 22 of Council Regulation (Euratom) 2018/1563 of 15 October 2018 on the Research and Training Programme of the European Atomic Energy Community (2019–2020) complementing the Horizon 2020 Framework Programme for Research and Innovation, and repealing Regulation (Euratom) No 1314/2013 (OJ L 262, 19.10.2018, p. 1).

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

[3] Further details on the methodologies adopted for this evaluation are provided in Annex 1.

- reports from the independent experts covering thematic areas (fusion, nuclear safety, radiation protection, radioactive waste management) of indirect actions funded under the Programme.
- a study by Ernst & Young consultancy on the governance and management of EUROfusion, and on fission research[5]

The feedback from an online public stakeholder consultation carried out in the context of this evaluation has also been used[6].

The main limitation of this evaluation is that, at this point in time, the picture of the Programme's results and impacts can only be partial. Evaluation is taking place only three years after the end of the Programme when almost a third of projects (31%) were only launched in 2020 and about half of the projects are still ongoing[7].

Though important results were observed, significant impacts such as influence on the regulatory framework or development of new materials or techniques would need more time to emerge. 'High-risk' actions (such as fundamental research) would also lead to have impacts which are in the longer term (e.g. 5-10 years, and even beyond) than 'low risk' actions with incremental and short-term effects, easier to detect and to report on. These long-term effects are also more difficult to capture through usual indicator systems and often need complex investigative work to match outputs from past projects with eventual impacts many years later, sometimes in different technical areas.

Data limitations include issues related to data availability and measurability of outcomes. Most of the Programme's Key Performance Indicators (KPI) focus on outputs from research projects such as publications and patents. Aggregation of this data is made difficult by the fact that the data comes from various sources while its reliability depends on self-reporting by project coordinators.

Another limitation is the lack of benchmarks to compare performance. Nowhere in the world is there a nuclear research programme similar to the Programme in terms of their broad thematic coverage and depth. To overcome and mitigate these limitations, this Staff Working Document is transparent in indicating its data sources and all underlying sources are available.

2. WHAT WAS THE EXPECTED OUTCOME OF THE INTERVENTION?

2.1. The Euratom Programme 2014-2020 and its objectives

Nuclear and radiation technologies have played and continue to play an important role in the lives of all Europeans, in energy and climate policies, security of energy supply and in non-power applications. The intervention logic of the Programme was to ensure the safe use of these technologies, striking the right balance between the need to support the safety of existing nuclear technology in Europe and the need to underpin safety in the future. Figure 1 (see next page) shows the intervention logic of the Euratom Programme

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4 Data on Euratom projects can be found on CORDIS website http://cordis.europa.eu/projects/home_en.html

5 Reports and studies are available at https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/euratom-research-and-training-programme_en

6 An analysis of the stakeholder consultation is provided in Annex V.

7 The COVID-19 epidemic led to prolongation of 6-12 months for many projects.

The objectives of the Programme were based on the compromise reached by the Commission and the Council following the Fukushima nuclear accident in March 2011. The general objective was to pursue nuclear research and training activities with an emphasis on continuous improvement of nuclear safety, security and radiation protection, notably to potentially contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way. The Programme's indirect actions had the following specific objectives[8]:

(a) supporting safety of nuclear systems

(b) contributing to the development of safe, longer-term solutions for the management of ultimate nuclear waste, including final geological disposal as well as partitioning and transmutation

(c) supporting the development and sustainability of nuclear expertise and excellence in the Union

(d) supporting radiation protection and development of medical applications of radiation, including, inter alia, the secure and safe supply and use of radioisotopes

(e) moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities

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

(g) promoting innovation and industrial competitiveness

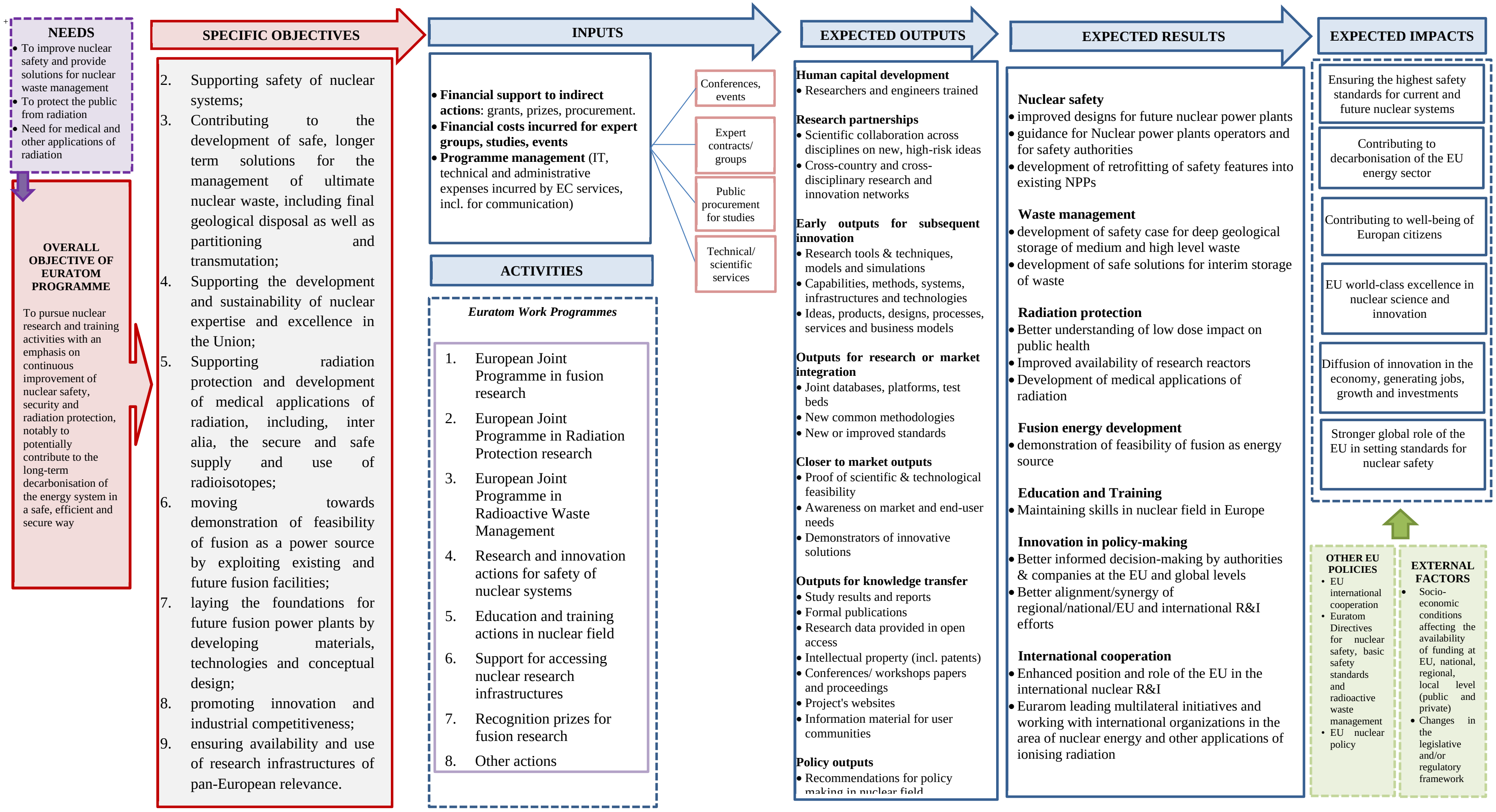
(h) ensuring availability and use of research infrastructures of pan-European relevance.

Regarding fusion research (points (e) and (f) above), Annex I to Council regulations further specified that a European Joint Programme should be established through co-fund grant.

8 See Article 3(2) of the Council Regulations 1314/2013 and 2018/1563. For more details see chapter 3 of Impact Assessment for 2014-2018 Euratom Programme SEC(2011)1427, Annex 6.

Figure 1

INTERVENTION LOGIC OF EURATOM PROGRAMME 2014-2020



Source: European Commission

2.1.1. *Indirect actions, Fission research*

The focus of research on safety-related issues addressed critical societal concerns regarding the use of current nuclear technology, such as the operational safety of nuclear power plants and safe disposal of the most hazardous forms of radioactive waste (high-level waste and spent nuclear fuel).

The increasing average age of the fleet of nuclear power plants in Europe required and still requires[9] a particular emphasis on their ageing and long-term operation strategies. Research is needed to understand degradation mechanisms of safety-relevant components and the impact on overall safety. This knowledge supports a science-based assessment of the safety margins and allows for the timely implementation of safety improvements. The predictive tools and assessment methods benefit periodic safety reviews of existing nuclear installations. They also help the regulators in assessing new designs.

All Member States generate radioactive waste through activities ranging from non-power applications to electricity generation and research. Owing to the potential radiological hazards it poses to workers, the public and the environment, radioactive waste and spent fuel must be safely managed through characterisation, minimisation of the amount of radioactive waste generated, containment and isolation from humans and the living environment over the long term. In this regard, the Programme aimed to improve the safe management of spent fuel and radioactive waste and reduce the risks.

Outside the power sector, the Programme addressed societal concerns regarding the use of nuclear technologies in medical diagnostic and therapeutic practices. Here, the focus was on the effects of low doses of radiation on humans. A multidisciplinary approach was needed to provide more detail on radiation benefits, risks and effects, including their interaction with other risk factors. These could pave the way for better recommendations and new solutions for health and environmental protection against the dangers of ionising radiation. Research should also provide insights into innovative and optimised medical procedures and their application in clinical practice.

By supporting this research, the Programme helped Member States and stakeholders in implementing the Nuclear Safety Directive[10], the Radioactive Waste Directive[11] and the Basic Safety Standards Directive[12].

2.1.2. *Indirect actions, Fusion research*

The Programme focused on developing fusion energy, a possible new 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 come with the safety risks and waste and proliferation issues as fission.

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9 In 2020 the mean age of the EU's nuclear reactor fleet in EU was 36.4 years (source: https://www.statista.com/statistics/1352921/mean-age-of-nuclear-power-reactors-eu/).

10 Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations (OJ L 172, 2.7.2009, p. 18).

11 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 (OJ L 199, 2.8.2011, p. 48).

12 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 (OJ L 13, 17.1.2014, p. 1).

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 the EU energy sector, contribution to the mitigation of climate change and to EU energy security, and improvement of the EU innovation and competitiveness (see Figure 2 with intervention logic).

It is however important to underline that, to this day, the delivery of fusion energy still faces immense scientific challenges. One key challenge is in the physics of plasmas, the state of matter needed for fusion[13]. Researchers do not yet fully understand the behaviour of burning plasmas whose main source of heat is from the fusion reaction itself rather than an external source. Researchers have made advancements in this area but lack sufficient experimental data to fully validate their simulations. One key engineering challenge is the development of materials that can withstand fusion conditions for years such as extreme heat and neutron damage and no facility yet exists where materials can be fully tested. More generally, the task of extracting energy from fusion to provide an economical source of electric power presents several complex problems in systems engineering that have yet to be solved, such as extracting fusion by products from the plasma, creating plasma-facing systems that are easily maintained and replaced, managing extremes of both heat (from plasma) and cold (for cooling superconducting magnets). The use of tritium fuel also raises supply, safety, and security concerns.

The EU has for many years been at the forefront of fusion research and the EU flagship experimental device JET (Joint European Torus), in operation between 1983 and 2023, achieved multiple records in 1997 and 2021[14] when it demonstrated operation with a plasma containing a mixture of the hydrogen isotopes deuterium and tritium, the fuel of future fusion power plants. Thanks to JET and other machines co-funded by the Programme, the basic physics understanding has progressed sufficiently to advance, in 2013, to the next stage: the start of construction of ITER (International Thermonuclear Experimental Reactor[15]) – a machine capable of producing fusion plasmas at the scale of future power plants and validating the current understanding of fusion science at reactor scale[16].

[13] For recent assessment of research challenges see US GAO report on *Fusion Energy: Potentially Transformative Technology Still Faces Fundamental Challenges* https://www.gao.gov/products/gao-23-105813

[14] In 2023, the JET facility released a record 59 megajoules of sustained fusion energy. This achievement more than doubles previous fusion energy record of 22 megajoules set in 1997. For more details see https://euro-fusion.org/eurofusion-news/european-researchers-achieve-fusion-energy-record/

[15] For more details see https://www.iter.org/

[16] For more details see https://www.iter.org/sci/Goals

Figure 2. **Intervention logic for fusion research under Euratom Programme 2014-2020**

Needs	Address Climate change	Address growing energy demand	Create sustainable long-term carbon free energy sources
General objective	**Demonstrate the feasibility of fusion as an energy source**		
Specific objective	*Moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities (including ITER);*	*Laying the foundations for future fusion power plants by developing materials, technologies and conceptual design;*	
Input	**EUROfusion consortium implementing the Fusion Roadmap, funded by the Euratom Programme 2014-2020**		
Activities	Research carried out through exploitation of multiple experimental facilities, implementing 8 Missions specified in the Fusion Roadmap	– Design and research activities aimed to develop the pre-conceptual design of a Demonstration Fusion Power Plant; – Research to advance the technical basis of a fusion power plant (materials, exhaust)	
Outputs	Milestones as specified in the Annual Work Plan	Milestones as specified in the Annual Work Plan	
Long-term Results	– Establishment of plasma regimes of operation – Full performance operation of ITER using deuterium-tritium fuel – Demonstration of the scientific and technical feasibility of fusion energy	– Establishment of a baseline architecture that integrates all the major DEMO sub-systems into a coherent plant concept – Complete integrated concept design – Design for construction – Construction of DEMO Power plant – Demonstration of the commercial and economic viability of fusion energy	
	New sustainable source of energy		
Long-term Impacts	**Improved environmental performance of EU energy sector**	**Mitigating climate change, contribution to EU energy security**	**Improved EU innovation and competitiveness**

Source: European Commission

While the deployment of fusion power plants that can contribute to the decarbonisation of the EU's energy mix still remains a distant prospect, the Programme aimed to move towards demonstration of feasibility of fusion as an energy source by exploiting research facilities and developing necessary materials, technologies and conceptual design. To achieve these two specific objectives (see figure 2), the Programme co-funded activities of EUROfusion, a consortium of Member States' research laboratories. As required by the regulations, the consortium implemented the European fusion roadmap with specific research tasks formulated in eight missions, with a view to meeting the long-term goal of producing electricity through fusion[17].

Establishment of the consortium and an agreement on the roadmap was one of tasks set by the Programme's legal base[18] as the had to address a number of issues, including:

- the criticality of ensuring that ITER succeeds in order to secure Europe's unprecedented investment in this project
- the importance of ensuring that Europe has the capacity to benefit from ITER by fully exploiting the possibilities provided by a successful ITER to address the longer-term challenge of fusion power
- the need to introduce greater focus and prioritisation in fusion research, with notably a transition away from a broad-based fusion programme aimed at exploring the fundamentals of fusion science towards the technological issues associated with fusion power plants
- the necessity of establishing and updating a common roadmap to facilitate the move towards more goal-oriented research.

To address these issues, a profound reorganisation of Euratom-funded fusion research was needed[19]. While the pre-2013 structure of the Euratom-funded fusion programme had served research well, by 2012-2013 it was considered as unsuitable to address future challenges, notably for a successful preparation of the ITER device and its eventual experimental exploitation and the post-ITER phase (see point 2.2. below). In the design of the Euratom Programme, by introducing the EUROfusion joint programme, the Commission sought to phase out instruments used to support the fusion research community which had become out-of-date, reduce administrative burden and continue with the transition, begun in the 1990s, from its role as an active coordinator and strategic leader to a funder with high-level oversight over the implementation of a roadmap defined by the fusion community.

17 https://euro-fusion.org/eurofusion/roadmap/

18 See point (i) of Annex I to Council Regulations 1314/2013 and 2018/1563

19 For comprehensive overview see Commission Staff Working Document SWD(2013) 213 'Towards a Modern Euratom Fusion Research Programme'.

2.2. Points of comparison

The evaluation is based on assessment of scientific and technical progress made in Euratom-funded fission and fusion research and effects of the introduction of new instruments such as European Joint Programmes. The two sections below provide an outline of the situation before the start of the Programme, while table 1 provides a more detailed list of the Programme's expected main outputs and results[20].

2.2.1. Indirect actions, Fission research

Evaluation of the fission research under the Euratom Programme 2014-2020 is based on the assessment to what degree outputs and results expected in 2014 (see table 1) have been achieved by the portfolio of projects selected following calls for proposals. The situation around 2013 in specific areas covered by the Programme can be summarised as follows:

a) Nuclear safety of existing and future power plants: Research was needed to address issues of relevance for Europe arising from a detailed analysis of the Fukushima accident, in particular identified in the 'stress tests' carried out in the EU. It was also important to maintain research on issues of importance to the existing fleet of reactors, in particular related to lifetime extensions and long-term operation. Key R&D issues were related to meeting safety requirements for long-term operation focussing on ageing of structures, systems and components. Other important issues were ageing mechanisms, monitoring and prevention and mitigation measures. Finally, research was needed on accident tolerant fuel performance. The focus on safety extended also to fundamental design work on the next generation of nuclear systems.

b) Management of spent fuel and radioactive waste: The R&D work carried out during 2000s has confirmed that deep geological disposal is the most appropriate solution for long-term management of spent fuel, high-level waste, and other long-lived radioactive wastes[21]. This scientific consensus had to be turned into an engineering reality, and this was the focus of attention during 2014-2020. Research in this area required further integration at European level[22]. In addition to the implementation of geological disposal of ultimate waste, it was of great importance to minimize upfront the waste production to the maximum extent.

c) Education and training in nuclear field: As a generation of nuclear physicists and engineers retires and a series of nuclear 'phase-out' policies in some Member States left a gap in new talent entering the workforce, education and training have become driving concerns for every sector in the nuclear field[23]. This is a crucial issue even for countries phasing out their nuclear programmes, as existing facilities need to be operated for at least the next 15 years. Nuclear expertise is also needed for all industrial and medical applications based on ionising radiations, as well as for decommissioning activities related to old nuclear installations. Maintaining knowledge in these disciplines, along with

20 Prepared on the basis of EUROfusion research roadmap, EJP's vision documents and Work Programmes.

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

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

23 Nuclear education and training: cause for concern? OECD NEA 2000

appropriate programmes of nuclear education and training, are essential prerequisites for a high level of nuclear safety and nuclear safety culture[24].

d) Radiation protection: During FP7 (2007-2012) the question was raised at European level of how low dose ionizing radiation health effects, and the biological mechanisms behind them, could be better understood through research. This would allow enhancing radiation protection, particularly in the medical practice of radiation, and in managing people, economic production and the environment after a contamination accident[25]. Research funded by Euratom under FP7 (2007-2012) while addressing pertinent issues was not sufficient to surpass the limits of the smaller separate projects hitherto allowed by the successive calls and national programmes. Further multidisciplinary research, integrating different scientific communities, was needed to determine the mechanisms involved and to quantify the risks of latent cancers and vascular diseases at these low doses[26].

2.2.2. Indirect actions, Fusion research

The start of ITER construction after the end of Euratom FP7 in 2013 marked the start of a new era for fusion research. While the Euratom-funded fusion research prepared the basis for ITER work, there was a growing consensus in the fusion community as documented by 2012 Commission Staff Working Document[27] that:

- The future European research efforts in the field of fusion must be reorganised and restructured to ensure the success of ITER while enabling Europe to benefit from this success.
- A common research roadmap between the national fusion associations is therefore needed to enable national and European resources to focus on ITER and its eventual exploitation. This roadmap should be developed, agreed upon and implemented by the national fusion labs by means of a joint programme coordinated by a dedicated legal entity; it should remain a living document requiring regular review and updating.
- The European fusion research programme during 2014-2020 should support the implementation of this joint programme, implemented by national labs.

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

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

[26] *Low dose effects research in Europe: eight years of evolution towards new paradigms*, J. Repussard, Radioprotection, 52 4 (2017) 251-258, DOI: https://doi.org/10.1051/radiopro/2017032

[27] See SWD(2013) 213 'Towards a Modern Euratom Fusion Research Programme'.

Table 1 - Expected main outputs and results of the Euratom Programme 2014-2020 (*Source: European Commission)*			
Fusion energy	**Nuclear Safety**	**Waste Management**	**Radiation Protection**
Introduction of a new organisation of fusion research for effective implementation of the Fusion roadmap: launch of European Joint Programme, update of fusion roadmap. **Development and qualification of plasma regimes of operation for ITER and DEMO (Mission 1)** - Further optimisation of plasma regimes of operation with metallic wall; - Further development of mitigation and control of disruption and runaway electrons; - Control of plasma edge instabilities; - Establishment of regimes of operation with high radiated power; - Enhanced predictive capabilities of fusion plasma performance by numerical simulations and validation of models. **Development of heat exhaust systems (Mission 2):** - Demonstration of significant reduction of tritium retention in plasma facing materials; - Completion of a preliminary design and technology development for the divertor; - Definition of the scope and feasibility of a divertor tokamak test facility.	**Safety of existing nuclear power plants:** - Better understanding of physical processes involved in nuclear reactors' anomalies and development of a non-intrusive innovative core-monitoring technique for detection and characterisation of anomalies; - Progress in development of accident-tolerant fuels; - Improved assessment techniques of structural integrity of nuclear power plants' components; - Better understanding of the ageing phenomena occurring in reactor pressure vessel steels. Development of predictive approaches in support of surveillance programs; - Establishment of a procedure for fatigue analysis in NPPs based upon experimental test data, integrating also impact of environmental effects; - Development of mitigation techniques for environmentally-assisted cracking of nuclear power plants components; - Improvement of the detection limits of the ultrasonic inspection techniques of complex structures; - Development of non-destructive evaluation tools for characterisation of	**Integration of research**: establishment of a European Joint Research Programme in the management and disposal of radioactive waste. **Geological disposal of HLW & SF:** - Development of means and conditions for a sustainable network of independent technical expertise for safety case reviews; - Improved knowledge on the impact of cement materials in contact with bentonite barriers and the host rocks on the mobility of radionuclides; - Assessment of the impact of microbial metabolisms on the safety of geological repositories; - Development and demonstration of monitoring strategies & technologies for geological repositories; - Development of tools for the assessment of the bentonite barriers mechanical evolution; - Improved understanding of the dissolution and chemistry of modern spent fuels in failed container conditions. **Management of other radioactive waste:** - Development and validation of new	**Integration of research**: establishment of European Joint Programme in radiation research (CONCERT), implementation of Strategic Research Agenda, implementation by CONCERT of a portfolio of projects in radiation protection; **Nuclear emergency preparedness**: Development of improved nuclear emergencies modelling for atmospheric dispersion, dose estimation, food chain and countermeasure simulations and their propagation in decision support systems **Radiation biology:** better understanding of low dose radiation induced effects at molecular, cellular and tissue level **Radioecology:** preparation of novel guidance documents for dose assessment, risk management, and remediation of radioactively contaminated sites **Supply of medical radioisotopes:** In order to maintain supply chain of medical radioisotopes, development of a new, safe, high-density fuel for high performance research reactors while addressing proliferation concerns.

Development of neutron resistant materials (Mission 3): Substantial progress in the qualification of the neutron resistant materials and in increasing their working temperature range. **Development of components to ensure tritium self-sufficiency (Mission 4):** Substantial progress in the design of the four breeding blanket concepts. **Implementation of the intrinsic safety features of fusion into the DEMO design (Mission 5):** Definition of the safety and licensing requirements. **Integrated DEMO design (Mission 6 & 7):** Pre-conceptual DEMO design activity, preparation of the Stakeholder and Plant Requirements document. DEMO-relevant samples of superconducting magnets fabricated and tested. Significant progress in the remote maintenance. **Stellarator development (Mission 8):** Commissioning and operation of the W7X facility.	the embrittlement level in reactor pressure vessels; - Updated elements for Probabilistic Safety Assessment of Nuclear Power Plants focusing on external natural events like earthquake, tsunami, flooding, high speed winds, etc.; - Further development of in-vessel retention of melted core; - Update and validation of simulation tools to improve accident management and emergency response; - Development of a backup cooling system to upgrade LWRs passive safety systems. **Future nuclear power plants:** - Improved modelling and safety assessment of different future reactor concepts; - Improvement of nuclear fuel cycles for advanced systems; - Qualification of structural materials for future nuclear systems; - Testing of safety features and waste management of future concepts; - Conceptual design for a high temperature nuclear cogeneration system to supply process steam to industry – licencing framework and business plan for full scale demonstration.	techniques for the characterization of conditioned radioactive waste; - Assessment of thermal treatment technologies providing waste volume reduction. **Decommissioning:** - Development of a roadmap for decommissioning research aiming at safety improvement, environmental impact minimisation and cost reduction; - Development of methodologies for more accurate estimation of the characteristics and the volume of contaminated materials as well as for improved Decommissioning and Dismantling (D&D) planning.	**Medical low dose radiation exposure:** Contribution to refined radiation protection in the medical field by: i) improving organ dose estimation, ii) evaluating the effects of low to moderate doses of radiation, with a focus on cardiovascular disease as a result of radiotherapy and cancer risk as a result of CT scans, and iii) formulating a series of evidence-based recommendations to improve radiation protection of patients, medical workers and general public.

3. How has the situation evolved over the evaluation period?

3.1. General overview

For the implementation of the Euratom Programme 2014-2020, the Commission signed 100 grants and other contracts with 796 organisations on behalf of Euratom to a total Euratom contribution of almost EUR 1 562 million (see table 2a below). Until 2024, the Commission paid 97% of committed funds (EUR 1509.15 million).

Table 2a: Number of signed grants and their value under the Euratom Programme 2014-2020

	Signed grants	Euratom contribution (million EUR)
Fusion research	2	1 123.8
Fission and cross-cutting research	98	415.5
Other		22.6
Total	100	1 561.9

Source: European Commission

The Commission monitored during seven years execution of the Programme using nine performance indicators (see table 2b below) set by the Regulations. Indicators show evolution of outcomes (projects) and results (publications, PhDs, milestones etc.) for Programme's specific objectives.

Table 2b - Key performance indicators per specific objective for indirect actions in fission and fusion research under Euratom Research and Training Programme 2014-2020								
Key performance indicator	2014	2015	2016	2017	2018	2019	2020	Total
Specific objective - Supporting the safety of nuclear systems								
The number of projects likely to lead to a demonstrable improvement in nuclear safety practice in Europe	9		23		28		47	47
Specific objective - Contributing to the development of safe, longer-term solutions for the management of ultimate nuclear waste, including final geological disposal, partitioning and transmutation								
The number of projects contributing to the development of safe long term solutions for the management of ultimate nuclear waste	5		10		11		12	12
The number of projects likely to have a demonstrable impact on regulatory practice regarding radiation protection and on development of medical applications of radiation	1		2		3		6	6
Specific objective - Supporting the development and sustainability of nuclear expertise and excellence in EU								
The number of researchers' and engineering grants in the Euratom fusion programme	17	28	28	33	32	26	34	198
The number of PhD students supported per year	675	675	751	751	751	726	734	
Specific objectives - Moving towards demonstrating the feasibility of fusion as a power source by exploiting existing and future fusion facilities & Laying the foundations for future fusion power plants by developing materials, technologies and conceptual design								
The number of publications in peer-reviewed high impact journals	77	367	289	427	548	783	2194	4685
The percentage of the Fusion Roadmap's milestones, established for the period 2014-2020, reached by the Euratom Programme	10%	28%	47%	66%	82%	90%	97%	97%
Specific objective - Promoting innovation and industry competitiveness								
The number of spin-offs from the fusion research under the Euratom Programme	1	2	2	2	3	5	6	6
The patents applications generated, and patents awarded on the basis of research activities supported by the Euratom Programme	1	2	1	3	2	4	6	19
Specific objective - Ensuring the availability and use of research infrastructures of pan-European relevance								
The number of researchers having access to research infrastructures through Euratom Programme support	872	958	1039	909	1350	1445	1734	8318

A detailed evolution and analysis of the implementation of the Programme is provided below.

3.2. Indirect actions, Fission research

During 2014-2020, the Commission had published five calls for proposals in fission research. Following evaluation by external experts, 98 projects were selected (Research and Innovation Actions, Coordination and Support Actions, European Joint Programmes (EJPs)), with a total Euratom funding of EUR 415 million (see table 3 below). On average, Euratom supported 72% of total costs of projects with contribution of EUR 4.24 million (excluding EJPs, Euratom support was EUR 3.86 million). On average each project included almost 20 participants, with total participation of 590 different organisations, taking part in multiple projects resulting in 1869 participations. In addition to research grants, the Commission acquired in 2016 and 2021, following a public procurement, 3% of access rights to Jules Horowitz Reactor (under construction in France) for total amount of EUR 21 million.

Table 3: Implementation of fission indirect actions during 2014-2020

	2014-2015	2016-2017	2018	2019-2020	Total
Contribution (EUR)	90 144 332	108 852 945	72 700 968	143 775 718	415 473 962
Total costs (EUR)	135 292 418	137 673 757	111 028 886	190 339 235	574 334 295
Support rate	67%	79%	65%	76%	72%
Number of grants	23	25	15	35	98
Unique participants	267	237	210	263	590
Time-to-Grant	251	229	235	237	Average 238

Source: European Commission

Commission selected and implemented Euratom projects directly without involvement of executive agency, reaching average Time-Time-to-Grant (TTG) of 238 days, below the target of 245 and the FP7 average of 313 days. Due to the long duration of projects (more than 4 years on average), about 46% of projects were closed at the time of the evaluation and 54% are still ongoing.

In terms of support for specific fission research fields (see table 4), the Euratom Programme 2014-2020 funded mainly projects for safety of nuclear systems, which accounted for more than half of the total funding (51%), followed by management of radioactive waste (22%) and radiation protection & medical applications (17%). The details about research subfields are discussed in section 4.

Euratom-funded projects engaged an estimated workforce of around 8 000 persons including 200 scientific managers (2%), 5 000 experienced researchers (63%), 500 researchers recruited (6%), 800 PhD partially or full-time in a project (10%) and 1 500 others (engineers, technicians, administrative support, 19%).

Table 4– Funding per specific objective of Programme (fission research, indirect actions only, Euro)						
Specific objective	**2014-2015**	**2016-2017**	**2018**	**2019-2020**	**Total**	**%**
Safety of nuclear systems	28 697 160	67 707 922	29 307 059	85 023 973	210 736 114	51%
Management of ultimate nuclear waste	25 299 129	19 455 489	32 500 000	14 000 000	91 254 618	22%
Supporting radiation protection and development of medical applications of radiation	26 172 551	9 995 146	6 999 989	25 959 173	69 126 858	17%
Development and sustainability of nuclear expertise and excellence	9 975 492	5 096 239	3 893 920	4 809 195	23 774 846	6%
Research infrastructures of pan-European relevance		6 598 148		13 983 377	20 581 525	5%
Total	**90 144 332**	**108 852 945**	**72 700 968**	**143 775 718**	**415 473 962**	100%

Source: European Commission

Regarding funds received and participation of Member States and third countries (see table 5), during 2014-2020 almost all Member States were involved in the fission research indirect actions with multiple participations in projects. Data shows that Euratom funding is highly concentrated in few Members States – the first three Member States in terms of grants awarded (France, Germany, Belgium) received more than half of all Euratom funds (52%), while organisations in top 10 countries received 88% of funds. Other Member, though receiving less, participated in many projects, with countries such as Spain, Italy, Finland, Czechia, Sweden involved in half of the research projects. Note the high position of two countries associated to the Euratom Programme: Switzerland and Ukraine. Other third countries, such as Japan, Norway, United States and Canada participated in around one-tenth of the projects, with very limited Euratom funding, only in cases where their participation was judged essential by evaluators.

Table 5: Funds from fission research grants received and participation of Member States and Third Countries		
Country	**Euratom grants received (EUR)**	**% of project involvement**
France	104 439 064	88%
Germany	59 046 253	84%
Belgium*	51 606 060	77%
United Kingdom	29 542 421	61%
Spain	24 746 489	63%
Italy	23 754 799	52%
Finland	21 039 980	55%
Czechia	17 937 122	61%
Sweden	16 812 212	48%
Switzerland	12 832 840	43%
Netherlands	11 974 440	35%
Hungary	6 765 938	31%
Slovenia	4 510 184	26%
Poland	4 341 567	25%
Slovakia	3 310 543	20%
Ukraine	3 270 176	18%
Austria	2 909 312	11%
Greece	2 297 677	13%
Lithuania	2 297 532	22%
Romania	1 576 441	20%
Portugal	1 185 373	11%
Bulgaria	1 167 012	10%
Denmark	805 976	6%
Estonia	660 755	4%
Ireland	570 047	4%
Luxembourg	324 396	1%
Norway	323 764	10%
Latvia	301 885	3%
Croatia	254 474	5%
United States	191 759	13%
Russia	156 502	7%
Cyprus	111 479	4%
Canada	11 200	9%
Japan	10 000	13%

**Belgium includes funds for JRC, Source: European Commission*

Involvement in multiple projects is also visible for Member States, which joined since 2004, in particular, Czechia, Hungary, Slovenia, Poland, Slovakia, Lithuania and Romania. New Member States which joined since 2004 are also becoming more frequently project coordinators. The grants for participants from the new Member States increased from EUR 9 million in 2014-2015 to almost EUR 18 million in the last call 2019-2020, reaching more than EUR 50 million over seven years (see table 6).

Member States not using nuclear power participate mainly in projects concerning radiation protection, medical applications and radioactive waste management. Some also participate in research for nuclear safety and nuclear data to maintain competences like Austria, Denmark, Greece, Ireland and Portugal.

Table 6: Statistics on participation of Member States in Euratom calls during 2014-2020 *('New Member States' = Member States joining in 2004 or later)*				
	2014-2015	**2016-2017**	**2018**	**2019-2020**
Total number of Member States involved	24	22	22	24
Average number of Member States per project	8.08	7.48	8.57	7.56
Number of projects with New Member States	21	22	13	29
Number of New Member States participations	90	68	61	99
% of projects with New Member States participation	91%	88%	93%	85%
% of participations from New Member States	22%	17%	21%	20%
Budget awarded to New Member States (EUR million)	9.1	17.6	7.7	18.2
% of total budget awarded to New Member States	10%	16%	11%	13%

Source: European Commission

Considering different types of organisations involved in Euratom-funded fission research (see table 7), we notice that research organisations (REC) are the most frequent type of beneficiary (39%) with the highest sum of grants (51% of total funding) followed by education establishments (HES, mainly universities) and private for-profit entities (mainly industry). The former includes also SMEs which accounted for 7% of all participations receiving EUR 24.44 million of funding during 2014-2020.

Table 7 – Statistics on involvement and funding for different types of organisations			
Type of organisation	**Participation**	**Unique Participants**	**Euratom grants (EUR)**
Research Organisations (REC)	731	136	210 409 138
Higher or Secondary Education Establishments (HES)	544	206	99 743 675
Private for-profit entities – PRC (excluding HES)	449	176	91 043 921
Other	77	35	4 025 099
Public bodies (excluding REC and HES)	68	37	10 252 129

Source: European Commission

Concentration of nuclear research, noted already in terms of funding per Member States is also visible when analysing the main grants beneficiaries (see table 10 on page 25). The first 20 recipients of the largest Euratom grants accounted for 48% of all funding in fission research, frequently playing a role of coordinator (61% of all projects).

Regarding results of the research, more than 77 projects (out of 98, 79%) prepared about 1700 publications, of which half were peer reviewed articles, the rest including conference proceedings, books and other publications. 18 projects without publications are mainly Coordination and Supporting Actions (CSA), with objective of supporting E&T and research infrastructures.

Turning to statistics on peer reviewed publications per Programme's specific objective, data shows that projects in three main research fields (safety, waste and radiation protection) produced 95% of the articles (see table 8).

Table 8: Peer review publications per specific objective of Programme (fission research, indirect actions only)			
Specific objective	**Number of peer review publications**	**%**	**Peer review publications per EUR 10 million funding**
Safety of nuclear systems	447	55%	21
Management of ultimate nuclear waste	187	23%	23
Supporting radiation protection and development of medical applications of radiation	139	17%	22
Development and sustainability of nuclear expertise and excellence	14	2%	6
Research infrastructures of pan-European relevance	29	4%	9
Total	816	100%	20

Source: European Commission

Data on publications per EUR 10 million funding shows a balanced productivity across the main fields (see table 14 above) and allows also a comparison with some of the priorities under Horizon 2020 (see table 9), such as ERC, Health and Energy. Note that Euratom-funded fission projects put frequently emphasis on specific deliverables for interim and end-users instead of peer-reviewed articles.

Table 9: Comparison of peer review publications per EUR 10 million funding from Euratom Programme and selected priorities under Horizon 2020 (data for 2014-2022)				
ERC: 89	Euratom (fusion): 63	Health: 48	Euratom (fission): 20	Energy: 9

Source: European Commission

Further data (see figure 3) shows a broad range of results in terms of publications (per EUR 10 million) from different projects grouped per topic (some topics in R&D for materials reach 90-70 publications per EUR 10 million).

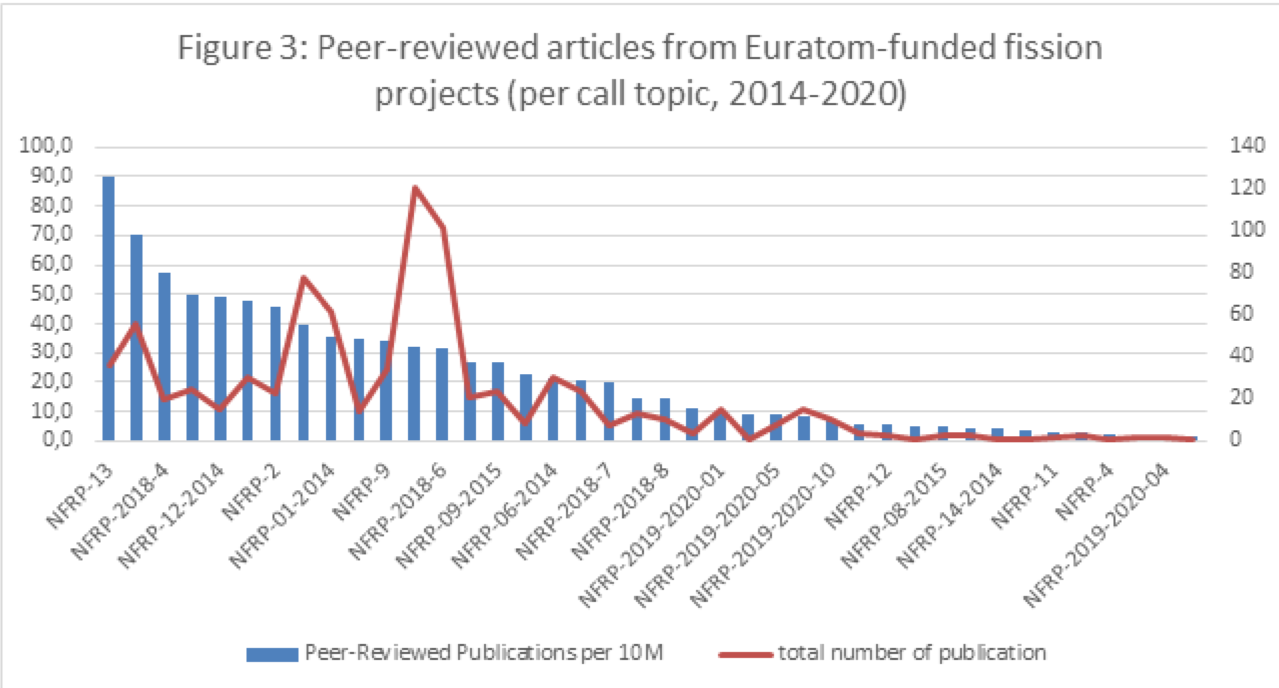

Figure 3: Peer-reviewed articles from Euratom-funded fission projects (per call topic, 2014-2020)

Table 10: Main players in Euratom funded fission research (first 10 recipients of grants in fission research)				
Organisation	**Country**	**Euratom grants received (EUR)**	**Projects involved**	**Coordination role**
STUDIECENTRUM VOOR KERNENERGIE / CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE	Belgium	29 260 248	46	4
COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	France	29 193 694	64	12
TEKNOLOGIAN TUTKIMUSKESKUS VTT OY	Finland	14 417 510	36	7
INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE	France	13 271 995	41	4
KARLSRUHER INSTITUT FUER TECHNOLOGIE	Germany	12 093 469	35	3
FRAMATOME	France	9 452 639	15	1
ELECTRICITE DE FRANCE	France	9 298 238	38	6
JRC - JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	Belgium	8 786 716	40	0
CENTRO DE INVESTIGACIONES ENERGETICA MEDIOAMBIENTAL Y TECNOLOGICA	Spain	8 145 857	35	6
ENEA	Italy	7 741 404	27	4
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France	7 231 331	22	0
PAUL SCHERRER INSTITUT	Switzerland	6 941 449	28	1
BUNDESAMT FUER STRAHLENSCHUTZ	Germany	6 120 773	4	2
UJV REZ AS	Czechia	5 715 518	29	1
HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF EV	Germany	5 649 399	20	1
CENTRUM VYZKUMU REZ SRO	Czechia	5 590 069	29	1
NUCLEAR RESEARCH AND CONSULTANCY GROUP	Netherlands	5 354 656	21	0
LGI SUSTAINABLE INNOVATION	France	4 901 793	17	1
NATIONAL NUCLEAR LABORATORY LIMITED	UK	4 783 686	17	0
AGENCE NATIONALE POUR LA GESTION DES DECHETS RADIOACTIFS	France	4 216 606	7	4

3.3. Indirect actions, Fusion research

The Euratom Programme 2014-2020 set two specific objectives in the area of fusion research and called for the establishment of the consortium to implement a research roadmap[28] :

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

In order to implement these lines of action and following the expiry of the Contracts of Association (CoAs) and European Fusion Development Agreement (EFDA), in 2014 the Commission put in place a different approach based on a European Joint Programme implemented by a consortium of Member States’ fusion labs in line with an agreed research roadmap to fusion electricity.

Following an independent experts’ evaluation of the proposal submitted by the consortium, in November 2014 the Commission awarded an EUROfusion grant of EUR 424.8 million[29]. The grant was topped up in 2018 to EUR 470.8 million for 2014-2018. An additional EUR 208 million was granted for 2019-2020[30].

This brought the total grant amount for 2014-2020 to EUR 678.8 million. The grant was limited to 51% of EUROfusion’s EUR 1 330 million total eligible costs. In 2020 the EUROfusion grant was extended to 2022 without additional funding to provide some continuity and a smooth transition to the Euratom Programme 2021-2025. The Euratom funding was paid in annual instalments, subject to EUROfusion reaching the milestones and providing deliverables. The annex to the initial Grant Agreement described the detailed implementation plan of the Fusion Roadmap for 2014-2018. In drafting the plan for the extension of the Grant Agreement for 2019-2020, the implementation plan was realigned with the 2018 update of the roadmap.

The grant to EUROfusion was supplemented by a New JET Operation Contract (NJOC), a bilateral contract based on Article 10 of the Euratom Treaty and signed on 6 June 2014 between the Commission and the JET operator, Culham Centre Fusion Energy (CCFE) in the UK). On the basis of this contract the Commission paid EUR 429 million over 2014-2021 for the exploitation of JET. JET was provided as an in-kind contribution to the Joint Programme implemented by EUROfusion which had the responsibility to elaborate the scientific programme for the exploitation of the machine.

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[28] Annex I, points (i), (e) and (f) of Council Regulation (Euratom) 2021/765.

[29] It was a grant to named beneficiary provided in the Euratom Work Programme 2014-2015 (C(2014)5009). Award of the grant was subject to positive outcome of the evaluation by external experts, using the same evaluation criteria and minimum scores as in the open call for proposals.

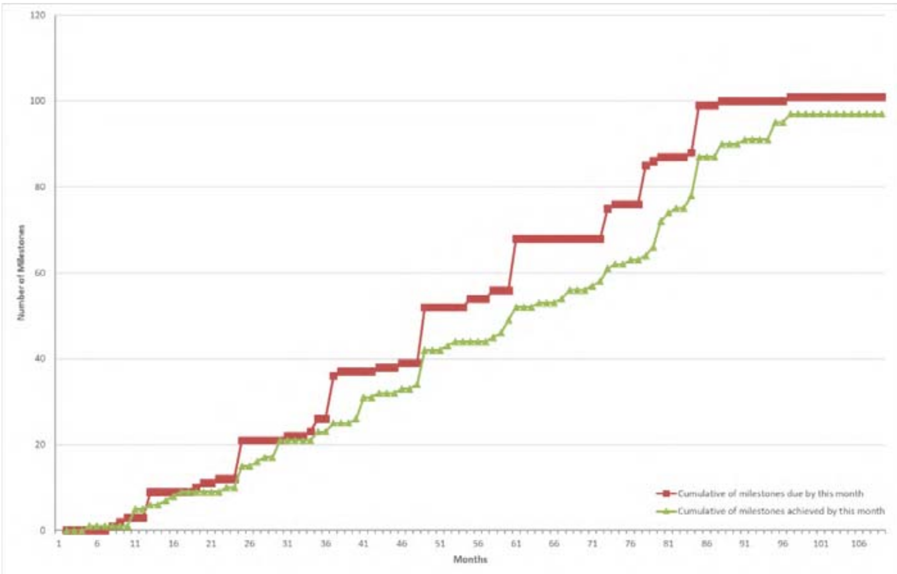
[30] Euratom Work Programme 2019-2020 (C(2018)8412)

During 2014-2021, EUROfusion carried out research organised in 33 work packages which focused on the implementation of the eight missions of the fusion roadmap. Most of the expected outputs and results have been achieved (see section 4 for discussion on the details).

Research priorities are clearly visible in terms of research efforts (personnel costs, Person Per Year, PPY) claimed by laboratories, with focus on ITER physics ~80% and physics & technology for future fusion power plant (10%) and education and training the remainder (10%).

Over 8 years, out of 101 milestones, EUROfusion achieved 99 (i.e. 98%). Two missing milestones have been transferred to 2021-2025 grant (see Fig 4). Linked to milestones, all the grant deliverables have been submitted by EUROfusion and approved by the Commission. Noteworthy is a delay at the start of the programme, which is on the one hand because the grant agreement was only signed in October 2014, even though it started retro-actively on 1 January 2014. During the year 2020, the gap between planned and achieved milestones/deliverables increased due to COVID related delays as well as a 1- year delay in the JET programme.

Figure 4: Progress in achievement of EUROfusion milestones



Source: EUROfusion,

In terms of publications, EUROfusion's research results were published in 5350 peer-reviewed publications (stand-alone and conference papers). The number of publications has increased year by year, apart from a decrease in 2021 due to the impact of COVID-19. After it was noted that many peer-reviewed papers included in the technical reports of different projects were not included in the EUROfusion database, a major correction was done in 2020. This explains the fact that in that year there are so many more database entries as in the years 2015-2018. Beside peer-reviewed papers, EUROfusion have also published more than 1500 unrefereed conference proceedings. Figure 5 gives an overview of all types of publications and their evolution over 2014-2020.

Figure 5*: Publications in peer-reviewed journals: stand-alone papers (left) and conference-related papers in special issues (right) based on the database entries. The labels are (year, number of publications)*

Source: EUROfusion

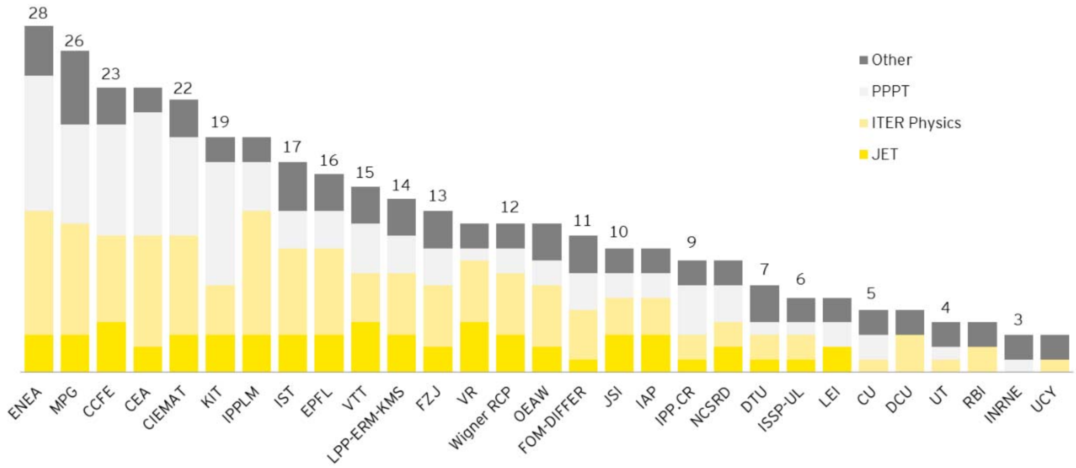
Resources and responsibilities within the various work packages were allocated to labs by EUROfusion through calls for participation, one at the outset in 2014 and later through the annual programming process.

Table 11: Distribution of staff effort and Euratom grant between members of EUROfusion consortium		
Laboratory	**Full Time Equivalent (FTEs)**	**Contribution from EUROfusion grant (EUR)**
MPG (DE)	1776.8	166 156 000
ENEA (IT)	3385.5	95 769 000
CEA (FR)	1128.5	73 847 000
CCFE (UK)	1017.4	55 598 000
KIT (DE)	897.2	55 516 000
EPFL (CH)	491.1	41 626 000
CIEMAT (ES)	854.6	35 004 000
FZJ (DE)	531.3	26 121 000
DIFFER (NL)	226.4	14 000 000
LPP-ERM-KMS (BE)	209.4	13 351 000
VR	215.8	11 811 000
IPPLM (PL)	499.3	10 677 000
VTT (FI)	154.4	9 916 000
IST	269.5	8 819 000
ÖAW	164.8	6 811 000
IPP,CR	238	6 613 000
NCSRD	193.1	5 027 000
JSI	134.5	4 655 000
DTU	66.5	4 277 000
IAP	106.9	3 831 000
WIGNER-RCP	155.4	3 755 000
ISSP-UL	67.4	1 893 000
CU	114.4	1 435 000
KIPT	247.6	1 344 000
DCU	37.8	1 246 000
RBI	26.5	1 184 000
UT	57.6	1 038 000
LEI	15	363 000
INRNE	47.9	323 000
UCY	1.9	56 000
TOTAL	13332.6	662 062 000

Source: European Commission, EUROfusion

Table 11 shows distribution of resources over 2014-2020. The distribution of funds reflects mainly the size of human resources involved in fusion research in specific labs as well as the number of EUROfusion packages they were participating in (see Fig. 6). Funding was concentrated in major labs, with the first three labs receiving half of the whole funding (note that the first lab, Max-Planck-Institut für Plasmaphysik was the coordinator of the consortium).

Figure 6: Participation in EUROfusion work packages by research labs



Source: European Commission, EUROfusion as provided by E&Y

Human resources - staff in research labs

Over 2014-2020, the population of researchers, engineers and support staff working in fusion labs, members of EUROfusion, was increasing steadily from 3079 in 2014 to 5815 in 2020 (see table 12). The gender balance continues to be skewed with only 23.25% females among the workforce contributing to EUROfusion. While similar figures are shared by many other engineering and scientific sectors, it is clear that the gender inequality in the fusion programme must be addressed more vigorously in the next programme. Meanwhile a post of Training and Education Manager has been created in EUROfusion with one of the objectives to increase gender balance.

Table 12. Number of EUROfusion contributors and gender balance

Year	Females	Males	Total	% Female
2014	565	2 514	3 079	18.1
2015	662	2 679	3 341	19.8
2016	751	3 057	3 808	19.7
2017	762	3 375	4 137	18.4
2018	791	3 006	3 797	20.8
2019	987	3 921	4 908	20.1
2020	1 033	3 782	5 815	21.5

Source: European Commission, EUROfusion

Mobility of researchers and scientists within EUROfusion was one of the cornerstones on which the success of research actions depended. Over 2014-2020, the number of persons using research facilities in other labs increased two-fold (see table 13). Mobility support covered funding for visiting scientists for joint research, long-term secondees, and fellowships. Within EUROfusion, mobility for joint research activities was approved in line with the project-oriented approach and was directly integrated into the programme budget and managed under the responsibility of each Project Leader and Taskforce Leader.

Table 13. Number of researchers with access to research infrastructures through Euratom Programme support	
Year	**Number**
2014	872
2015	958
2016	1 039
2017	909
2018	1 350
2019	1 456
2020	1 734

Source: European Commission, EUROfusion

Education and training

One of the principal objectives of EUROfusion in 2014-2020 was to ensure the availability of appropriate human resources in the fusion research effort over the longer term, particular in view of the need to train scientists and engineers able to operate and exploit ITER, and to ensure the right balance and competences of physicists and engineers in a DEMO programme focusing increasingly on conceptual design activities and engineering design activities. One of the tasks of the EUROfusion consortium was to support PhD students in the research institutions working on fusion-relevant thesis subjects, i.e. mainly on fusion plasma physics and engineering. The allocation of funding to individual research institutions was based on the number of students and theses supported each year and a quality assessment of the student training provided[31]. Furthermore, the thesis subjects were screened by EUROfusion to ensure they are relevant for the fusion roadmap implementation. Table 14 shows the evolution of the budget for PhD students and number of active students for each year[32].

Table 14. Number of PhD students and budget allocated							
Year	2014	2015	2016	2017	2018	2019	2020
Number of students per year	675	675	751	751	751	726	734
Budget (EUR million)	9	7.9	8.1	8.6	8.6	8.6	8.6

Source: European Commission, EUROfusion

Master Students were not directly funded by EUROfusion. During 2014-2020 several dedicated Fusion Master programmes were supported in Europe by the FUSENET Association[33] who were a linked third party to EUROfusion. The number of active fusion master students was estimated around 200-250 during 2014-2020.

31 EUROFUSION GA (16) 13 - 4.6 Fusenet PhD Assessment Final Report (1-March-2016)

32 Note that before 2019 the database was updated once every three years, explaining why for 2015 and also for 2017 and 2018 the same numbers as in previous years were used. The numbers for 2019 and 2020 are taken from the education reports. A few countries didn't report their student numbers.

33 See https://fusenet.eu/education/study

Fusion research and technology development requires staff with skills going beyond PhD level. For this reason and in order to maintain highly qualified staff, EUROfusion has set up in 2014 the EUROfusion Researcher Grants (ERG) and the EUROfusion Engineering Grants (EEG). The EEG topics mainly target engineering and technology challenges of the highest priority and/or scarce competences where the community needs more experts in the near future. The ERG are post-doc grants to scientists who have recently finalised their PhD, while EEG aims to encourage excellence and career development of young engineers.

Table 15: Engineering Grants (EEG) and Researcher Grants (ERG) supported by EUROfusion

	2014	2015	2016	2017	2018	2019	2020	Total
Engineering Grants (EEG)		17	17	22	19	15	22	112
Researcher Grants (ERG)	17	11	11	11	13	11	12	86
Total	**17**	**28**	**28**	**33**	**32**	**26**	**34**	**198**

Source: European Commission, EUROfusion

Support for EEG grants is constantly adjusted to the expected shortage of skills in specific missions of the fusion roadmap. The total number of EEG and ERG grants reached 198 during 2014-2020 (see table 15), while engineering grants (112) exceeded number of researchers grants (86). This indicates that the fusion programme is increasingly recognising the key role engineering and technology is playing in the push for a DEMO programme. Data shows that a retention rate for ERG and EEG trainees is fairly high, with 82% and 73% of finished trainees working in fusion research.

Following the introduction of prizes in Horizon 2020's rules for participation shared with the Euratom Programme, the Commission launched in 2014 a European Prize for Innovation in Fusion, the SOFT Innovation Prize, in association with the Symposium on Fusion Technology (SOFT) biennial conference. The objective of the prize is to reward outstanding researchers or companies trying to find new solutions, possibly with broader applications, to the challenges of fusion development. During 2014-2020, the Commission organised four editions, attracting 37 proposals and producing nine awards for EUR 300 000.

4. EVALUATION FINDINGS (ANALYTICAL PART)

4.1. To what extent was the Euratom Programme 2014-2020 successful and why?

4.1.1. Indirect actions, fission research

In fission research, the Euratom Programme 2014-2020 can be considered as a success both in terms of implementation and results demonstrated until 2023.

For the Programme's implementation, as shown in section 3, the European Commission managed to launch a broad portfolio of projects covering a wide range of issues in nuclear safety (ageing of NPPs, LTO, future systems), radiation protection and radioactive waste management. Funded projects covered mainly safety aspects as agreed in post-Fukushima compromise in the Council. Despite the fact that Euratom funding is highly concentrated in few Members States, mainly using nuclear power, almost all Member States were involved in the fission research indirect actions with many cases of multiple participations in projects.

Strong involvement was visible for Member States, which joined since 2004, in particular, such as Czechia, Hungary, Slovenia, Poland, Slovakia, Lithuania and Romania, showing that in EU nuclear research there is limited evidence for an East-West division in this area. Member States not using nuclear power, also benefited from access to the Programme, largely in projects concerning radiation protection, medical applications and nuclear waste management. Some also participate in research for nuclear safety and nuclear data to maintain competences like Austria, Denmark, Greece, Ireland, Portugal. From a general perspective, the Programme contributed to efforts by all Member States to build consensus around the highest standards of safety in all applications of ionising radiation.

The evaluation noted a high concentration of nuclear research, both in terms of funding per Member States and per main beneficiaries, leading to the development of a network of major R&D organisations, maintaining strong competences in all key areas of nuclear expertise as shown by the coordinator role played by many of them.

The evaluation showed evidence that the Euratom funded projects delivered impacts and supported redefining the 'state of the art' in the main fields of fission research (see thematic sections below for details). These findings are also confirmed by stakeholder consultation. Overall, 88% of stakeholders were positive concerning the impact of projects in which they participated, while only 7% did not agree. For 43% of respondents, the first type of impact appears to be the development of significant new knowledge in the various fields covered by the Euratom fission projects, followed by new knowledge leading to a redefinition of the accepted state of the art in the field (31%). 12% answered that research led to reduction of uncertainties or refinement of existing models and techniques. Stakeholders had also clarity on who were the main end-users of projects: 57% indicated nuclear industry, 49% universities and training authorities, one quarter of respondents indicated nuclear safety, radioactive waste management and radiation protection authorities.

***a)* Supporting the safety of nuclear system[34]s;**

In nuclear safety, the evaluation concluded[35] that projects have provided relevant results and, in some cases, made a significant progress with respect to the original state of the art in the following areas:

- Advanced computer models and simulations for safety analysis, including severe accident, of different reactor systems (Gen II and III) – projects CAMIVVER, McSafe, McSafer;
- Strategies for severe accident management to ensure in-vessel retention of melted reactor's core (projects IVMR, MUSA);
- Contribution to safety demonstration and safety assessment of generic design of Gen IV reactors (project EFSR-SMART) as well as testing and qualification of safety relevant components[36];
- Databases on accident scenarios for all existing and new types of NPPs in Europe (project FASTNET);
- Databases on irradiated materials and models for assessment of long-term integrity of primary systems and components (Project ENTENTE);
- Testing protocols for fatigue testing of NPP components (projects INCEFA-SCALE, INCEFA-PLUS);
- Innovative backup cooling system that can be retrofitted into existing NPPs and included in future NPPs (projects sCO2-HeRo, sCO2-4-NPP);
- Development of advanced materials for nuclear systems, including computer models to evaluate radiation effects, development of new structural materials and their stress testing (projects M4F, GEMMA and ORIENTNM);
- Tools and methods for safe decommissioning and dismantling, which should facilitate DD and reduce risks (projects INNO4GRAPH, PLEIADES, INSIDER)[37].

These findings are also confirmed by feedback from the stakeholders who indicated that the Euratom projects were:

- Creating new knowledge to contribute to the continued safe operation of existing reactor systems (e.g. plant life assessment, safety culture, numerical simulation tools, instrumentation, etc.) – 50% respondents said yes, while 25% did not agree.
- Addressing new challenges (e.g. lifetime extension and development of new advanced safety assessment methodologies) - 49% of respondents said yes, while 26% did not agree.
- Contributing specifically to the development and/ or maintenance of a high level of safety - 63% of respondents said yes, while 21% did not agree.

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34 Full overview of Euratom-funded research projects in this area is provided in - European Commission: Directorate-General for Research and Innovation, Procházka, O., Iorizzo, A. and Rossetti di Valdalbero, D., *Nuclear safety research – The results of the Euratom research and training programme*, Procházka, O.(editor), Iorizzo, A.(editor) and Rossetti di Valdalbero, D.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/605392

35 Ex-post evaluation of indirect actions for reactor safety under Euratom Research and Training Programme 2014-2020, Stefano Monti, 2023

36 See also *Review of Euratom projects on design, safety assessment, R&D and licensing for ESNII/Gen-IV reactor systems*, Konstantin Mikityuk, Miguel Ferreira, Branislav Hatala, Jan Leen Kloosterman and Monika Šípová, EPJ Nuclear Sci. Technol., 9 (2023) 18, DOI: https://doi.org/10.1051/epjn/2022048

37 See also *European collaborative efforts to achieve effective, safe, and cost-controlled dismantling of nuclear facilities*, Nicolas Malleron, Michèle Guerin, Damien Roulet, Maugan Michel, Cédric Rivier, Philippe Lefevre and Marie-Bénédicte Jacques, EPJ Nuclear Sci. Technol., 9 (2023) 6, DOI: https://doi.org/10.1051/epjn/2022041

- Addressing technologies linked to the performance of future reactor systems (e.g. Gen IV, small modular reactors, etc.) - 42% of respondents said yes, while 31% did not agree.
- Assessing the safety and waste management aspects of future reactor systems (e.g. Gen IV, small modular reactors, etc.) - equal percentage of respondents (37%) agreed and disagreed with the statement.

In some cases, outputs and deliverables are already being used by projects' stakeholders. These results provide mainly tools for intermediate and final end-users of research including nuclear vendors, safety authorities, Technical Safety Organisations and, ultimately, NPP operators. This evaluation estimates that such results should enhance EU capabilities in the safety demonstration of existing and forthcoming reactors; however longer terms impacts need to be confirmed by studies on uptake of the research results by end-users. The fact that Euratom project consortia typically include a substantial number of end-users, should improve the translation of research results into end-user needs.

The evaluation[38] indicated that the set of seven Euratom-funded projects[39] addressing primary system and component long-term integrity is very comprehensive—it ranges from Reactor Pressure Vessel (RPV) damage and embrittlement to primary system piping degradation, pressurised thermal shock impact, and RPV integrity. However, expert noticed some redundancies and overlaps when looking at these projects together. To avoid duplications and ensure efficiency and synergies in the future, it is recommended that these activities be clustered in a unique project on RPV material test and analysis to ensure RPV integrity. In view of the expert, Euratom research programmes have always excelled in advanced modelling and simulation, mainly when dealing with different reactor systems' safety analysis, including severe accident analysis. This is confirmed by projects like CAMIVVER, McSafe, and McSafer, as well as other projects with solid modelling and simulation components like IVMR and MUSA[40]. An issue that deserves to be further understood and investigated is whether the Euratom-funded projects are well integrated with sometimes significant national efforts in the field to realise a European research area in modelling and simulation for the safety of nuclear installations.

b) contributing to the development of safe, longer-term solutions for the management of ultimate nuclear waste, including final geological disposal as well as partitioning and transmutation;

The aim of the Euratom Programme 2014-2020 was to address the remaining critical challenges in the geological disposal of spent fuel and long-lived radioactive waste. It supported joint programming efforts to help Member States develop and implement their national programmes for the safe, long-term management of all types of radioactive waste. This approach took into account the varying levels of advancement in each Member State's national programme and aligned with the requirements set by Directive 2011/70/Euratom ('Waste Directive')[41].

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[38] Ibidem

[39] Projects STRUMAT-LTO, NOMAD, SOTERIA, ENTENTE, FRACTESUS, ATLAS+, APAL.

[40] See also: *Towards an optimized management of accidents*, Luis E. Herranz, Gonzalo Jiménez and Francesco S. Nitti, EPJ Nuclear Sci. Technol., 8 (2022) 43, DOI: https://doi.org/10.1051/epjn/2022019

[41] 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. OJ L 199, 2.8.2011.

Before initiating the EURAD European Joint Programme, the Commission launched a broad range of projects addressing many specific scientific and technological issues in the waste characterisation, treatment, disposal and monitoring (CEBAMA, DISCO, CHANCE, BEACON, THERAMIN, SITEX II, MODERN2020, MIND). The evaluation[42] found that these projects substantially contributed to the development of a knowledge base for the safety case of deep geological disposal of radioactive waste, monitoring strategies and specific technologies.

The evaluation[43] concluded that the Euratom Programme, by introducing and developing Joint Programming in JOPRAD project and EURAD European Joint Programme on Radioactive Waste Management, successfully evolved from a traditional approach focused on the disposal system towards an approach encompassing all aspects of the management of radioactive waste and spent fuel in line with the requirements of the waste directive. This approach was further reinforced by the PREDIS project dedicated to predisposal activities for waste streams for which no industrially mature solution exists[44]. Joint programming was a paradigm change as the research needs were identified on a consensus-based approach in which different waste management organisations, technical safety organisations and research entities were involved. A Roadmap with clear objectives linking research activities listed in a Strategic Research Agenda to the different phases of a waste management programme has been developed[45]. That roadmap now allows Member States to identify the knowledge and capabilities needed to implement a disposal programme on a common base.

During 2014-2020, significant progress[46] was made in the Member States towards the implementation of geological disposal of radioactive waste and spent fuel, as shown by the granted licenses for repositories in crystalline rock in Finland and Sweden, the submission of the construction and operating license application for a repository in clay in France and siting progress, e.g. in Switzerland. This indicates that different concepts of geological repositories in various host rocks have reached the necessary scientific and technological maturity to support a safety assessment and industrial deployment. In those advanced Member States, the strong national R&D programmes as well as the Euratom co-funded projects over decades, including the EURAD and other 2014-2020 projects, were essential to reach the current status of implementing geological repositories. Throughout the successive research programmes, the uncertainties, e.g. concerning disposal performances and safety margins, were progressively identified and addressed at the right level and consequently, the knowledge base to build the safety case was solidly established. First steps have been taken to identify areas for optimisation and potential technological innovations. Less advanced Member States where field activities have not yet started or countries at an early-stage planning to develop a nuclear programme profited from access to the existing scientific and technological basis.

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42 Ex-post evaluation of research for the management of radioactive waste under the Euratom Programme 2014-2020, Jean Paul Minon, 2023.

43 Ibidem.

44 For examples of innovation in this area see https://predis-h2020.eu/wp-content/uploads/2024/10/PREDIS_D1.6-Case-studies-and-blogs_vFinal-09-2024.pdf

45 For overview of the process, see *EURAD − the European Joint Programme for research on radioactive waste management between EU members states national programmes*, Marie Garcia, Tara Beattie and Stéphan Schumacher, EPJ Nuclear Sci. Technol., 6 (2020) 21, DOI: https://doi.org/10.1051/epjn/2019044

46 See also articles in: European Commission, Directorate-General for Research and Innovation, FISA 2022 – 10th European Commission conferences on EURATOM research and training in safety of reactor systems & radioactive waste management – Conference proceedings. Volume 1 & 2, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/09868

The evaluation[47] also concluded that a community was constituted around the EURAD EJP, sharing a common culture on radioactive waste management, able to debate and improve knowledge, approaches and tools, as well as to analyse further alternative solutions, such as new materials for waste packaging[48]. The EURAD EJP also successfully set the framework for long-term knowledge management and for greater involvement of civil society and end-users. Waste Management Organisations and Technical and Scientific Support Organisations were systematically involved in the definition of the scope and the follow-up of the different EURAD projects. They made an essential contribution to defining the principles and the scope of Joint Programming.

Regarding education and training in radioactive waste management, Euratom-funded projects (EURAD, Predis) organised training courses, supported about 46 PhD students and provided 156 mobility grants

c) **supporting radiation protection and the development of medical applications of radiation, including, inter alia, the secure and safe supply and use of radioisotopes**

The Evaluation[49] concluded that the Euratom Programme 2014-2020 made substantial progress beyond the current state-of-the-art in the science-based evaluation of radiation risks from low doses of ionising radiation. The Euratom Programme has also provided critical support to structuring and coordinating low dose research in Europe by launching the CONCERT European Joint Programme for the integration of radiation protection research.

The Euratom Programme reinforced a multidisciplinary approach in radiation protection research to advance the understanding of radiation risks by encompassing several of the basic scientific disciplines, such as biology, biophysics, epidemiology and dosimetry, besides the specific disciplines about radiation protection so far, such as emergency preparedness, radioecology, or the medical use of ionising radiation. The Euratom Programme has been successful in the area of radiation protection in bringing together, within CONCERT, several research platforms, organizations and institutions for the first time in the EU and to develop in 2020 the first joint roadmap for radiation protection research. Lessons learned from drafting the CONCERT roadmap are already reflected in developing the more specific Strategic Research Agenda (SRA) in the medical field, published in August 2023 by the project EURAMED. It provides a European research roadmap[50] for policymakers, funders, as well as the scientific and clinical communities interested in research, innovation and training related to medical applications of ionising radiation, highlighting current challenges and areas where research efforts are needed to ensure accessible, highest-quality, and safe, personalised care for Europe’s patients.

CONCERT has prepared and made available a data base of relevant research infrastructures operated in EU member countries, a list of existing databases, including banks of biological material – facilitating access to research infrastructures and expanding cooperation between stakeholders in Europe. Within its education and training effort, CONCERT has set up a system of student travel

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47 EURAD final review, presentation by Gerald Ouzounian, April 2024

48 For details see https://www.ejp-eurad.eu/publications/eurad-d117-evaluating-impact-european-programme-radioactive-waste-management

49 Ex-post Evaluation of indirect actions in Radiation Protection under the Euratom Research and Training Programme 2014-2020, Helena Janžekovič, 2023

50 European Commission: Directorate-General for Research and Innovation, *Medical applications of ionising radiation for better patients’ lives – A European research roadmap*, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/27769

grants to attend relevant training courses at other institutions, to present their work, and to attend conferences. A call for short courses in topics important for radiation protection research, aimed particularly at students entering the field or young researchers has also been launched. This further developed and sustained expertise and competence of research scientists in the area of radiation protection.

The CONCERT conducted two open calls for proposals, selecting 9 research projects[51] that produced promising results in different areas:

- Guidance on the management of uncertainties present in decision making process in emergency exposure situation (project CONFIDENCE)
- Tools for management of occupational exposures at workplaces where ionising radiation is linked to induction of cataracts (project LDLensRad);
- Recommendations for reducing uncertainties in human and ecosystem radiological risk assessment and management in nuclear emergencies and existing exposure situations (project TERRITORIES);
- Recommendations to public authorities for enhancing civil society engagement in the governance of radiation risks in emergency preparedness, response, indoor radon and medical exposure (project ENGAGE);
- improved understanding of how low doses radiation induce leukaemia (project LEU-TRACK);
- proved the feasibility of performing personal dosimetry of occupationally exposed workers using computational methods, which would give significant advantages compared to physical dosemeters and improve implementation of radiation protection in line with the Basic Safety Standards Directive (project PODIUM);
- improved understanding the radiation effects on a tissue which is not directly irradiated (project SEPARATE).

Overall, the experience of implementing the first joint programme in radiation protection, particularly the establishment of the research roadmap helped concentrate efforts around the most relevant topics and provided important lessons for establishing the European Partnership in this field under the Euratom Programme 2021-2025.

While the introduction of joint programming in radiation protection research was the main focus of the Commission, the Euratom Programme 2014-2020 funded also 4 further projects addressing risks related to radon and medical applications of ionising radiation[52, 53].

In the last decades, the use of ionising radiation in the medical area, particularly in oncology, has dramatically expanded. While benefits are evident, increasing medical exposures requires attention to minimise detrimental effects on the exposed patients and to optimise radiation protection of all involved in medical procedures. The SINFONIA project introduced a novel approach, based on AI, to dose estimations in the medical field and developed innovative risk appraisal tools. The

51 https://www.concert-h2020.eu/en/deliverables/research-projects

52 Ex-post Evaluation of indirect actions in Radiation Protection under the Euratom Research and Training Programme 2014-2020, Helena Janžekovič, 2023

53 See also *Medical applications of ionizing radiation and radiation protection for European patients, population and environment*, Isabelle Thierry-Chef, Elisabeth Cardis, John Damilakis, Guy Frija, Monika Hierath and Christoph Hoeschen, EPJ Nuclear Sci. Technol., 8 (2022) 44, DOI: https://doi.org/10.1051/epjn/2022044

HARMONIC project built two cohorts of paediatric patients treated with ionising radiation for long-term follow-up, focusing on the late effects of exposures such as secondary cancers. It paved the way towards quantifying risks associated with ionising radiation, understanding the mechanisms behind detrimental effects and better optimising medical exposures. The MEDIRAD project developed tools for improving organ dose estimation to inform clinical practice and improved understanding of the effects of medical exposures in breast cancer patients and from CT in children. It developed science-based policy recommendations for the adequate protection of patients and staff. The contribution of the Euratom Programme to risk assessment and optimisation of radiation protection, as well as in managing radon and naturally occurring radioactive materials (NORM), is clearly demonstrated by the ongoing large RadoNorm project[54].

Regarding education and training in radiation protection, Euratom-funded projects supported about 20 PhD students, provided mobility grants to 83 researchers (CONCERT EJP), and organised about 62 training courses.

4.1.2. Indirect actions in fusion research

The evaluation highlights the tangible and incremental progress made toward two specific objectives of the Euratom Programme 2014-2020: demonstrating the feasibility of fusion as a power source and preparing for future fusion power plants. To achieve this progress, the organisation of Euratom-funded fusion research required a new approach, as mandated by the Council regulation. In 2014, the European fusion laboratories established a different research organisation, a European Joint Programme centred around the fusion roadmap based on eight thematic missions. The roadmap represented a comprehensive and detailed goal-oriented approach to the challenge of developing magnetic confinement fusion as an energy source. Its implementation allowed for making considerable steps towards ensuring the success of ITER and advancing the technical basis of a future fusion power plant.

The details of the Programme’s achievements are presented below per specific objective:

d) Specific objective: ‘Moving towards demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities’

An independent evaluation[55] and EUROfusion reports[56] show that the consortium has substantially reduced during 2014-2020 the risks and enhanced the projected ITER performance, increasing confidence that ITER will reach its ultimate goals.

EUROfusion has developed a scientific programme of experiments and modelling on devices with different sizes, i.e., on medium-size tokamaks and on JET to provide a stepladder approach for extrapolations to JT-60SA, ITER and DEMO. Because it was closest in size and shape to ITER, JET was the most important worldwide facility in the ongoing programme to prepare for ITER operation. Indeed, ITER was largely designed on the basis of JET’s performance with a carbon wall. However, the carbon wall retained substantial quantities of tritium and was consequently not compatible with the future safe operation of ITER. Thus, the carbon wall was removed from JET and replaced with an

54 *RadoNorm – towards effective radiation protection based on improved scientific evidence and social considerations – focus on RADON and NORM*, Ulrike Kulka, Mandy Birschwilks, Laureline Fevrier, Balázs Madas, Sisko Salomaa, Aleš Froňka, Tanja Perko, Andrzej Wojcik and Nadja Železnik, EPJ Nuclear Sci. Technol., 8 (2022) 38, DOI: https://doi.org/10.1051/epjn/2022031

55 Ex-post evaluation of indirect actions in fusion research and development under Euratom Research and Training Programme 2014-2020, Steven Cowley, March 2023

56 Summarised in EUROfusion replies to Commission questionnaire on 2014-2020 Euratom Programme

"ITER like" Tungsten-Beryllium wall in 2011. The fusion performance of JET with the new wall was unfortunately severely degraded in the initial operation. This raised understandable concern for ITER's prospects. Thus in 2014 the most important issue facing fusion science was to understand the degradation and improve the performance of JET. This investigation has been highly successful. The record breaking 59MJ of fusion energy delivered in shot 99971 on the 21st of December 2021 is a clear demonstration of that success. All scientific results give confidence that ITER can reach its ultimate goals once operational. In a very real sense JET has completed its nearly 40-year mission and confirmed its place as one of the most successful Euratom facilities.

While the JET result provides the headline goals and integrated scenarios for ITER, it is backed by substantial progress on understanding the plasma physics of confinement from across the EU. This is codified in the predictive simulation tools that have been validated against experimental results across Europe.

Key highlights indicated by independent experts are:

- The development of the plasma exhaust system (the so-called divertor) on ADEX upgrade at IPP Garching, JET, MAST in the UK and TCV in Lausanne. In these experiments, small quantities of impurities (mostly neon or nitrogen) were introduced into the fusion plasma to radiate the exhaust heat and prevent erosion of the divertor wall. Models now predict that introducing similar impurities in ITER would mitigate excessive erosion.
- Tungsten is an ideal fusion wall material in many ways – it is tough and has low erosion rates. Thus, tungsten will be employed in ITER and probably in future fusion reactors. However, if tungsten accumulates in the plasma, it is a problem since it radiates and cools the fusion fuel. ASDEX and JET have developed techniques to limit tungsten accumulation.
- Explosive instabilities called disruptions can rapidly release the fusion plasma energy to the walls. On current devices these instabilities are relatively benign. However, on ITER such instabilities will, over time, damage the wall. Techniques to mitigate disruption damage with massive injection of gas or frozen fuel pellets have been developed and tested on JET and ASDEX upgrade. These techniques coupled with machine learning predictions of imminent instability provide ITER with an effective risk mitigation. ITER will be the first device heated by the alpha particles from the fusion reactions themselves. Unfortunately, fusion alpha particles can drive instabilities that expel the particles before they can heat the fuel. Since 2014 experiments at JET, ASDEX upgrade and TCV have helped develop accurate simulations of the process. It is clear that these instabilities can be avoided in ITER.
- The central weakness in the ITER preparation is in the analysis tools. The computational tools to predict, analyse and interpret experimental results have not substantially improved during 2014-2020. While the tools have been adequate for JET and ASDEX operations, a greater ambition to produce comprehensive intershot analysis is required under the 2021-2025 Programme.

e) Specific objective: 'Laying the foundations for future fusion power plants by developing materials, technologies and conceptual design'

The independent evaluation[57] and EUROfusion reports show[58] that substantial progress has been made under the 2014-2020 Euratom Programme in the specific technologies for the future fusion

[57] Ex-post evaluation of indirect actions in fusion research and development under Euratom Research and Training Programme 2014-2020, Steven Cowley, 2023

power plant (materials, breeding blankets etc.) and the DEMO design effort. Candidate materials have been selected for all components of future fusion reactors, although final choices are not yet determined. Detailed analyses for the future fusion power plant have revealed optimum material choices to minimize the fusion waste streams. The design of IFMIF-DONES neutron source has been developed and a site (Granada, Spain) selected. This will become the leading test facility for fusion materials and remains an essential tool to develop materials that will retain structural integrity when bombarded by fusion neutrons. The foundations are established – in the next decade the testing will begin once appropriate infrastructure is available. Two tritium breeding blanket concepts prepared by EUROfusion for absorbing neutrons from fusion reactions and for breeding tritium fuel are well advanced and further work on test blanket modules should illuminate the issues for further research. The engineering work behind the DEMO pre-conceptual design is of high quality. It has brought much greater clarity to a number of critical design issues, and the overall integration challenge. Nonetheless, the DEMO research has not yielded a conceptual design of sufficiently low risk – particularly in plasma scenarios and power handling – to proceed to engineering design.

A summary of expected and delivered results grouped by 2014-2020 Programme's specific objectives and roadmap missions is provided in table 16.

[58] Summarised in EUROfusion replies to Commission questionnaire on 2014-2020 Euratom Programme

Table 16: Results expected and achieved by fusion R&D activities funded by Euratom Programme 2014-2020		
Programme's specific objective	**Main results per EUROfusion Roadmap mission expected in 2014** *(source: Fusion roadmap, interim evaluation)*	**Results achieved in 2014-2020**
Demonstration of feasibility of fusion;	**Development and qualification of plasma regimes of operation for ITER and DEMO (Mission 1)** – Further optimisation of plasma regimes of operation with metallic wall; – Further development of mitigation and control of disruption and runaway electrons; – Control of plasma edge instabilities; – Establishment of regimes of operation with high radiated power; – Enhanced predictive capabilities of fusion plasma performance by numerical simulations and validation of models.	Expected results have been achieved culminating in the successful experiments on JET and the D-T experiments. *Source: Peer-reviewed article[59], Cowley report[60], EC annual assessment of EUROfusion reports.*
Demonstration of feasibility of fusion; Foundations for future fusion power plants;	**Development of heat exhaust systems (Mission 2):** – Demonstration of significant reduction of tritium retention in plasma facing materials; – Completion of a preliminary design and technology development for the divertor; – Definition of the scope and feasibility of a divertor tokamak test facility.	Expected results have been achieved. *Source: Peer reviewed articles[61], Cowley report, EC annual assessment of EUROfusion reports.*
Foundations for future fusion power plants;	**Development of neutron resistant materials (Mission 3):** Substantial progress in the qualification of the neutron resistant materials and in increasing their working temperature range.	Considerable progress made in the area. Support provided to the design of the DONES material test facility which construction has begun in Spain *Source: peer reviewed articles[62], Cowley report, EC annual assessment of EUROfusion reports.*
Foundations for future fusion power plants;	**Development of components to ensure tritium self-sufficiency (Mission 4):** Substantial progress in the design of the four breeding blanket concepts.	Two blankets' designs defined, and further research defined *Source: Cowley report, peer-reviewed articles[63], EC*

59 Overview of JET results for optimising ITER operation, J. Mailloux *et al* 2022 *Nucl. Fusion* 62 042026.

60 Ex-post evaluation of indirect actions in fusion research and development under Euratom Research and Training Programme 2014-2020, Steven Cowley, 2023

61 Latest results of EUROfusion plasma-facing components research in the areas of power loading, material erosion and fuel retention, M. Reinhart et al 2022 Nucl. Fusion 62 042013; The DTT proposal. A tokamak facility to address exhaust challenges for DEMO: Introduction and executive summary, R. Albanese et. al, Fusion Engineering and Design, Volume 122, November 2017, Pages 274-284.

62 European materials development: Results and perspective, G. Pintsuk et. al, Fusion Engineering and Design, Volume 146, Part A, September 2019, Pages 1300-1307, (2) Bernardi, D., Ibarra, A., Arbeiter, F. et al. The IFMIF-DONES Project: Design Status and Main Achievements Within the EUROfusion FP8 Work Programme. J Fusion Energy 41, 24 (2022).

63 Status of maturation of critical technologies and systems design: Breeding blanket, L.V. Boccaccini et al, Fusion Engineering and Design, Volume 179, June 2022, 113116.; Progress in EU Breeding Blanket design and integration, F. Cismondi et al, Fusion Engineering and Design, Volume 136, Part A, November 2018, Pages 782-792.

		assessment of EUROfusion reporting
Foundations for future fusion power plants;	**Implementation of the intrinsic safety features of fusion into the DEMO design (Mission 5):** Definition of the safety and licensing requirements.	Lessons learned from ITER, and recommendations given on the route to regulate fusion outside of the Fission regulation (work started under 2014-2020 Programme, finalised in 2023). *Source: EUROfusion report*[64]
Foundations for future fusion power plants;	**Integrated DEMO design (Mission 6 & 7):** Pre-conceptual DEMO design activity, preparation of the Stakeholder and Plant Requirements document. DEMO-relevant samples of superconducting magnets fabricated and tested. Significant progress in the remote maintenance.	Preconceptual design was not completed, but the technical challenges were identified, with some preliminary assessment of technical solutions and clear R&D priorities defined for the next phase. *Source: DEMO Gate Review report*[65]*, Cowley report, peer-reviewed articles*[66]*.*
Demonstration of feasibility of fusion/ Foundations for future fusion power plants;	**Stellarator development (Mission 8):** Commissioning and operation of the W7-X facility.	W7-X facility commissioned and operational since 2015. *Source: Peer-reviewed articles*[67]*, EC assessment of annual EUROfusion reporting.*

f) Promoting innovation and industrial competitiveness

Euratom actions in this area focused on technology transfer from the research co-funded by the Programme to industry and on promoting innovation through, inter alia, open access to scientific publications.

FUTTA (Fusion Technology Transfer Activity) is EUROfusion’s action to promote the technologies developed by the European fusion laboratories by making them widely available and commercially viable to industry. The pilot was launched in 2012-2013, and FUTTA II was implemented during the 2014-2020 Programme with a budget of about EUR 0.4 million. Conducted through a network of facilitators (brokers) in France, Italy, Belgium, Germany, Spain and the United Kingdom, the project supported dissemination and exploitation of intellectual property rights from EUROfusion beneficiaries to the non-fusion industry. This work led to the definition of technology descriptions and their match with existing industrial needs, which eventually culminated in actual technology transfers. The FUTTA support allowed for the identification of the most innovative cutting-edge fusion technologies with the following results:

– 4 demonstrator project founded[68] and 8 technology transfers made[69];

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64 EUROfusion report on the Regulation of Fusion Power Plants, EUROFUSION GA (23) 42 - 4.10.
65 DEMO Gate Review Panel report (EUROfusion) https://euro-fusion.org/eurofusion-news/expert-panel-demo-design/
66 Special Issue of Fusion Engineering and Design (Volume 175, February 2022, 112939) on European Programme towards DEMO: Outcome of the Pre-Conceptual Design Phase;
67 Overview of first Wendelstein 7-X high-performance operation, T. Klinger *et al* 2019 *Nucl. Fusion* 59 112004

- 30 fusion technologies promoted to highlight the excellence of fusion research and the business value of the technologies developed;
- 30 needs collected from the industry to increase interest from non-fusion companies through technology matchmaking regarding their needs.

Open access to research results has the potential to improve scientific research (through improved reproducibility), involve citizens and society as well as accelerate innovation. The Commission integrated open access to scientific peer reviewed publications in the rules for Horizon 2020 and Euratom Programme 2014-2020 and promoted it with Member States and with stakeholders. For Euratom funded research, the data[70] shows open access to 73% (fission) and 64% (fusion) of peer reviewed scientific publications. For the latter, data for articles published in 2020-2021 show improving trend, reaching 71%.

g) Establishment of EUROfusion and reorganisation of European fusion programme

The architecture of the Euratom-funded fusion research underwent a major restructuring with the launch of the Euratom Programme 2014-2020. Fusion research had long been a field apart, both due to the nature and scale of the undertaking, but also due to the unique mix of instruments used for its implementation and the strong coordination role of the Commission. The introduction in 2014 of the European Joint Programme required the integration of national efforts across Europe including research activities in some 33 separate work packages (projects and taskforces), also covering education and training actions, international cooperation aspects, industrial involvement, centralised programme management, and the transnational access to experimental facilities.

Such a large and comprehensive joint programme necessarily required a complex governance structure and management system It was subject to an in-depth assessment by Ernst & Young consultancy which concluded that[71]:

The EUROfusion organisational structure provides stronger leverage in order to better focus efforts on the roadmap; 100% of European funding for the European fusion programme is now funnelled through one organisational framework. The structure is entirely constructed around the purpose of implementing an objectives-based programme of research aligned with the Roadmap. EUROfusion had been able to instil a culture of adherence to the Roadmap and a programming process that, while burdensome, ensured the alignment of annual activities with the Roadmap.

Despite the clear link between the Roadmap and the EUROfusion multiannual work programme, this connection in practice has become obfuscated by a cultural and procedural fixation on reporting and planning on the basis of the generic deliverables in the grant agreements rather than actual results.

The organisation established in 2014 inherently promotes a maximum level of cooperation and collaboration between research labs. Whereas joint collaborative projects before 2014 were a relatively small and peripheral part of the European fusion programme, they are now the cornerstone of it. In summary, the purely multilateral nature of the organisation means that energies are entirely

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68 Demonstrator projects include: (1) Casting mould materials made of tungsten fibre composites for high-temperature die casting; (2) Protective tungsten-based coatings for combustion chamber for aerospace applications, (3) Tungsten alloys for extended life corona discharge electrodes for applications in surface cleaning, air treatment and cooling electronics; (4) Algorithms for rationalization of fibre optics manufacturing.

69 For more details see http://techtransfer.euro-fusion.eu/index.php/success-stories/ This website will be replaced by https://fusion-technology-transfer.europa.eu/ (a new joint initiative of F4E and EUROfusion)

70 Data from Scopus (2024)

71 Ernst & Young France, Management and governance assessment of EUROfusion.

focused on collaboratively implementing the joint programme rather than simply striving to achieve the coordination of national programmes.

EUROfusion has succeeded in introducing an increased level of competition between labs, which has contributed to shifting mentalities from a logic of "spreading the money around" to constructing results-oriented teams and matching skills and competencies with project needs. However, there remains a strong culture of inclusiveness that contributes to the fragmentation and bloating of project teams and a dampening of the effects of an increased focus on excellence.

EUROfusion promotes greater transparency and understanding due to its centralised nature. The General Assembly is also better placed to be able to effectively monitor and steer the programme. Whereas the system was previously characterised by its highly fragmented nature with some 30 CoA and a relatively small multilateral component, EUROfusion now centralises all activities within the framework of one organisation. The entirety of European supported activities thus falls within the purview of the General Assembly and are monitored and reported on together following streamlined processes. Improved transparency facilitates also the work of the Commission services that retain overall monitoring and assessment responsibilities.

Finally, despite the strong sentiment of research stakeholders that EUROfusion was "imposed" in 2014 by the Commission, the organisational structure of the consortium also appears to promote greater ownership of the roadmap and its successful implementation by labs. This is further reinforced by the transition of the Commission to a role as a funding agency rather than an active scientific stakeholder in the coordination and leadership of the fusion research.

The E&Y report provided a large number of specific recommendations to the EUROfusion management for the improvement of governance and management which were included in the Commission report on the interim evaluation of the Programme[72]. Some changes were introduced shortly after the mid-term review in 2017-2018[73]. More substantial changes were taken into account in the set up for 2021-2025.

h) Supporting the development and sustainability of nuclear expertise and excellence in the Union (cross-cutting objective)

Fusion research : development of human resources and continuous emphasis on excellence were imperative to the successful implementation of the long-term vision of the European fusion research outlined in the EUROfusion Roadmap. The former was supported by different EUROfusion actions presented in section 3, while the SOFT Innovation Prize highlighted and rewarded excellence in innovation in fusion research as well as the quality of the researchers and industries involved.

In the area of education and training, data from EUROfusion show positive trends in the number of PhDs and post-doctoral fellows which should allow keeping the manpower of the fusion programme at a level required for the implementation of the roadmap and with the right balance of competences, in line with the conclusions of the Review of Human Resources in the European Fusion Landscape (2016)[74]. In response to the review results, EUROfusion has strengthened educational activities under the FuseNet Association, supported early career scientists and engineers with the EUROfusion

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72 COM(2017) 697, Report from the Commission to the European Parliament, the Council, and the European Economic and Social Committee. Interim evaluation of the Euratom Research and Training Programme 2014-2018. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0697

73 Details of changes provided in EUROfusion replies to Commission questionnaire on 2014-2020 Euratom Programme.

74 EUROFUSION GA (16) 13 - 4.5

Researcher and Engineering Grants focusing on scarce skill areas, and continued to align its E&T activities to the roadmap.

The evaluation pointed that a major challenge for future fusion development lies outside the usual skills of scientists and engineers (skills embodied in PhD and Masters qualifications)[75]. Indeed, fusion development will demand skills in project engineering. ITER has faced this issue and many projects across the Euratom fusion community are similarly challenged. While this element is expected to be delivered by industry, some input from EUROfusion is required since specialised fusion knowledge is often needed.

The data show that the SOFT Innovation Prize in fusion research has seen a steady increase of applicants and quality of applications over the years. Since the start of the Prize in 2014, coverage of different technologies relevant for fusion and broader applications has expanded further and further including vacuum and pumping technology, radiation detectors and innovative sensors, supercapacitors, advanced materials, high temperature superconductors, CAD-based nuclear engineering and modelling software. The winner researchers get top visibility and high international profile with potential for spin-offs and highly skilled jobs. They are acting as role-model for the fusion research community and are also better recognised.

In fission research, the Commission implemented a number of indirect actions to support researchers access to research facilities. Following public procurements in FP7 and 2014-2020 Programme, Euratom owns 6% of the access rights to Jules Horowitz Reactor (JHR) to carry out experiments for the Euratom scientific and research community. The JHOP 2040 project (Jules Horowitz Operation Plan 2040) elaborated the operation plan for the irradiation experiments at JHR, once exploitation will start in 2030s. Another project, TOURR, analysed EU research reactors' landscape, drew a roadmap for the upgrade of the existing RR fleet, and developed a model for harmonized resource utilisation[76].

4.2. Efficiency

This section reports the actual costs of the Euratom Programme's indirect actions for different stakeholder groups. It also assesses how simplification measures performed relative to targets and objectives. This evaluation is based on findings of the final evaluation of Horizon 2020[77], as the Euratom Programme was implemented using Horizon 2020 rules of participation[78]

4.2.1. Costs of the Programme

Implementing the Programme gave rise to several types of costs incurred by different stakeholder groups. The operational expenditure of the Programme for indirect actions is estimated at EUR 1509 million[79]. It is funded through the Union's budget and allocated to research and innovation projects. The administrative expenditure is about EUR 95 million. Beneficiaries' administrative costs are compensated by grant payments and included in the operational expenditure. Indicated time cost

75 Ex-post evaluation of indirect actions in fusion research and development under Euratom Research and Training Programme 2014-2020, Steven Cowley, 2023.

76 European research reactor strategy derived in the scope of the towards optimized use of research reactors (TOURR) project, Annals of Nuclear Energy, Volume 211, February 2025, 110963, https://doi.org/10.1016/j.anucene.2024.110963

77 For the details see section 4.2. of SWD(2024) 29

78 In line with the Council regulation establishing the Euratom Programme (Article 7(1))

79 State of play for 2024

range between 4.5 to 7 person-days per month of project duration. This implies that, if expressed as indicative money value, the total cost amounts to between EUR 12 million and EUR 20 million[80]. Application costs (the cost of preparing and submitting proposals) are covered by successful and unsuccessful applicants up front. The evaluation estimates that an average cost of a proposal falls into the range of EUR 18 000 to EUR 37 000, which suggests that successful proposals (98) may have cost EUR 1.8 million to EUR 3.6 million to prepare. The total application cost embodied in the large number of unsuccessful proposals is likely even more substantial and may well reach a value in the order of EUR 3 million to EUR 6 million[81].

While the costs associated with the Programme are incurred early on, its benefits[82] only emerge over a long period. It is difficult to measure in monetary terms the scientific and technological progress made by the Programme in nuclear safety, security and radiation protection, which is helping to ensure that Europe meets the highest standards in these fields. For this reason, the most appropriate approach is to measure the effectiveness of the research in terms of specific examples of results/impacts and scientific outputs. In the case of Horizon 2020[83], a much larger research programme covering a broad spectrum of research subjects, the closest available proxy for total benefit of this programme is the macro-economic forecast of its long-term GDP impact. Based on the above, the benefit-cost ratio (dividing total benefit by total cost) is around 5, consistent with a high value-for-money that reflects the potential of R&I support to generate substantial benefits over a long time horizon. It suggests that one euro of costs to society associated with Horizon 2020 (programme costs and costs to applicants) is estimated to bring about five euros of benefits for EU citizens (measured through GDP impact) up to 2040.

4.2.2. Performance of Programme's simplification measures

The Euratom Programme was based on Horizon 2020s rules. Optimising programme delivery has been one of Horizon 2020's specific objectives.[84] Simplification[85] aimed at:

1. Reducing administrative costs of applicants and beneficiaries in terms of the time, money and effort involved in participating in Horizon 2020[86], thus increasing the overall programme efficiency.
2. Accelerating all processes relating to proposal and grant management[87], thereby increasing the efficiency of administering the programme.
3. Decreasing the financial 'error rate' for Horizon 2020[88] would increase the efficiency of the programme's administration by the EU public sector and reduce administrative costs for beneficiaries.

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80 The confidence in these values is very low due to the small sample of respondents. For the details, see section 4.2. of SWD(2024) 29.

81 The confidence in these estimates is very low due to a lack of systematic and robust evidence. The estimates should be read as rough illustrative figures only. For the details, see section 4.2. of SWD(2024) 29.

82 See Section 4.1.

83 Section 4.2. of SWD(2024) 29

84 Regulation No 1291/2013, Framework Programme for Research and Innovation, Preamble 20.

85 Horizon 2020 - The Framework Programme for Research and Innovation, COM(2011) 808 final.

86 Simplifying the implementation of the research framework programmes, 2010/2079 (INI); Horizon 2020 - The Framework Programme for Research and Innovation COM(2011) 808 final.

87 Horizon 2020 - The Framework Programme for Research and Innovation, COM(2011) 808 final, p. 7.

Consequently, two main strands of simplification measures introduced for Horizon 2020 were also applied to the Euratom Programme[89]:

- Structural simplification and a general overhaul of implementation processes, primarily targeting simplification objectives 1 and 2, and as a secondary effect, objective 3 above.
- Simpler funding rules and a revised 'control and risk strategy'. These measures primarily set out to optimise the balance between the administrative costs of beneficiaries (objective 1) and the benefits of reducing financial errors (objective 3).[90]

As confirmed by the European Court of Auditors' report[91] 'the majority of the simplification measures effectively reduced the administrative burden for beneficiaries in Horizon 2020', and consequently also for the Euratom Programme. It but also pointed out that 'not all actions produced the desired result and opportunities to improve still exist'[92]. A 2022 study on the proposal evaluation system[93] found that evaluation processes were fair and transparent, although the overall consistency and the feedback provided to applicants could be improved.

Specific simplification measures implemented for the Euratom Programme included the introduction of a single regulation replacing separate FP7 specific programmes for indirect and direct actions and specific Euratom rules for participation. The Programme also stopped funding the Euratom's contribution to the ITER International Organisation. The new single regulation[94] covered all relevant aspects for implementing research activities. The Programme's architecture brought together previously separate actions in fission and fusion research, into one framework, governed by a single set of rules, shared with Horizon 2020, requirements and processes with common guidance documents and support services. The harmonisation of rules for participation and IT solutions for grant management and reporting, shared by Euratom with Horizon 2020, was highlighted as a 'major contribution' to simplification[95].

Another step in the simplification of the Euratom Programme' implementation was achieved by the introduction of European Joint Programmes (co-fund actions). EJPs allowed the Commission to respond to the need to refocus fusion research, align national strategies in fission research, and build a critical mass to ensure the scale and scope required. The Commission pushed for greater use of joint programming and co-fund instruments to take research coordination one step further and break with the historical paradigm of project-based support under Euratom FP7. This paradigm shift promoted much greater ownership of the research fields for the beneficiaries. At the same time, it created much more demanding project management responsibilities for beneficiaries than a classic collaborative project. This was further reinforced by the transition of the Commission to a role as a funding agency rather than an active scientific stakeholder in the coordination and leadership of the research (in fusion R&D).

Two quantitative targets allow tracking of the aggregate impact of the simplification measures on EU public sector administrative efficiency and can be assessed. First, the Euratom Regulations set out an

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88 COM(2011) 808 final. Management Measures, simplification p. 97; Regulation(EU) 1291/2013, Framework Programme for Research and Innovation, Preamble 20.

89 See sections 4.2.2.1 and 4.2.2.2 of SWD(2024) 29

90 Horizon 2020 - The Framework Programme for Research and Innovation, COM(2011) 808 final, p. 8.

91 Court of Auditors, Special Report No. 28 (2018).

92 Ibid. Executive Summary.

93 Study on the proposal evaluation system for the EU R&I framework programme (2022), op. cit.

94 Council Regulation (Euratom) 1314/2013 and Council Regulation (Euratom) 2018/1563

95 Court of Auditors, Special Report. No 28 (2018), Conclusions, p. 48.

overall efficiency benchmark for the programme's administrative expenditure for indirect actions of no more than 7% of the budget envelope for 2014-2018. Throughout the Programme, the administrative expenditure was also to decrease, aiming at a target of 6% or less in 2018 and then during the 2019-2020 extension[96]. The Programme's administrative expenditure implementation suggests that the Programme performed well against these benchmarks: the average for 2014-2018 was 6.38%, reaching 4.64% in 2018. During 2019-2020 extension, the administrative expenditure was at 5.69%, well below the target of 6%. For 2014-2020, the administrative costs represented about 6.16% of the total costs of indirect actions.

Second, several time targets were set for specific administrative processes[97], particularly the time-to-grant (TTG) target. Each grant agreement had to be signed 8 months (245 days) after the deadline for submission of proposals. Horizon 2020 (including Euratom Programme) was expected[98] to reduce the average 'time to grant' by 100 calendar days relative to FP7. The European Commission was able to process proposals for Euratom calls and grant agreements faster without a corresponding increase in the human resources involved. The achieved time-to-grant periods[99] show that the 2014-2020 Euratom Programme outperformed FP7, even relative to its more stringent target (245 days). The average time-to-grant period was 238 days. This means that 75 days were saved per grant on average compared to FP7, which had an average TTG value of 313 days. Given the 2014-2020 Programme's total of 98 grants signed, this means in aggregate about 20 years of working time in the EU public sector were saved relative to the time it would have taken if FP7's average TTG performance had continued. The introduction of an electronic grant management workflow and the withdrawal of the negotiation stage were identified by ECA[100] as key factors behind the sizable reduction, with beneficiaries broadly welcoming the withdrawal of the negotiation stage.

4.3. Complementarity of the Euratom programme with national research priorities and activities

The Euratom indirect actions in fission and radiation protection seek to accommodate for the needs of an extremely wide diversity of Member States, ranging from small Member States with no civil nuclear programme and almost no nuclear research activities, to large Member States meeting a large majority of their energy needs from nuclear power and on the international forefront of research. Even amongst the 13 Member States with civil nuclear programmes, the level of maturity of these programmes, the technology underlying their reactor fleet, the strategic orientations for the future development and the research needs and interests can differ significantly[101].

Considering these boundary conditions, the evaluation found that the Euratom Programme is generally coherent with the fission research priorities and activities on the national level:

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96 Art.4(1) of the Council Regulation (Euratom) 1314/2013: "For the implementation of indirect actions of the Euratom Programme, the Commission's administrative expenditure shall reach up to 7 % on average during the duration of the Euratom Programme and no more than 6 % in 2018". Art.4(1) of the Council Regulation (Euratom) 2018/1563: 'For the implementation of indirect actions of the 2019–2020 Programme, the Commission's administrative expenditure shall account on average for no more than 6 % of the combined total of the amounts set out in points (a) and (b) of the first subparagraph during the duration of the 2019–2020 Programme.'

97 Regulation 2021/695, Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013. Art 31.

98 COM(2011) 0808

99 Monitoring data on FP7 and Horizon 2020 (as of 1 January 2023).

100 Court of Auditors. Special Report. N.28. Evidence from survey and interviews, primarily from beneficiaries.

101 For more details see Ernst & Young study on fission research

- In the area of nuclear safety, Euratom priorities are well aligned with the needs of an ageing reactor fleet, addressing the inherent safety concerns arising from lifetime extension, as well as more generally improving knowledge of plant behaviour and performance and refining and developing new mitigation measures to respond to new risks as they appear (e.g. issues raised by the Fukushima accident). Most of the operating reactors were built in the 1970s and 1980s, and since the construction of reactors has slowed down in the last 30 years, the average age of the nuclear fleet has been continually growing during implementation of Euratom the Programme and reached 36,4 years in 2020. The 2011 Fukushima accident revived public concerns for the safety of NPPs and has led to national authorities strengthening their research programmes in this area, as well as the trend towards greater international cooperation in this field. The lessons learnt during the accident have also contributed significantly to shaping research priorities since 2011.
- Concerning research on advanced reactor systems, the Euratom programme has been focused on better understanding of safety implications arising from the development of advanced reactor concepts. Research priorities have been generally well focused on the most promising concepts being developed on the national level. They also generally complemented well national activities and provided small but useful support in the financially precarious early phases of concept definition and design.

The stakeholder consultation also confirms that findings, as about 66% of respondents agreed that the Euratom programme is aligned with national priorities[102], while 21% disagreed.

The coherence between Euratom and national programmes was facilitated by cooperation between the Commission and Member States in the Euratom Programme Committee. The drafting process and the discussion in the Committee helped ensure that the call topics set in the Work Programme covered issues relevant to the EU as a whole and for each Member State.

The Euratom programme has also responded to the need and desire of Member States to better structure cooperative research activities, notably in the domain of safety and management of radioactive waste and in radiation protection, by introducing joint programming.

- In the field of spent fuel and radioactive waste management, Member States' waste management organisations and technical support organisations made an essential contribution in defining the principles and the scope of Joint Programming. The EURAD roadmap allowed Member States to identify, using a common base, knowledge and capabilities needed to implement national disposal programmes[103].
- In radiation protection, the CONCERT's joint roadmap and EURAMED's SRA demonstrated consensus among different platforms, paving the way to better integration of European and national research programmes and pooling of resources. The evaluation concluded that it could be reasonably assumed that such integration is taking place in participating Member States. However, evidence on the alignment of national research priorities in radiation protection and links between national agendas was limited[104].

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[102] See questions 22 and 23 in Annex on consultation

[103] Ex-post evaluation of research for the management of radioactive waste under the Euratom Programme 2014-2020, Jean Paul Minon, 2023.

[104] Ex-post Evaluation of indirect actions in Radiation Protection under the Euratom Research and Training Programme 2014-2020, Helena Janžekovič, 2023.

4.4. External and internal coherence of the Euratom programme

The Euratom Programme is coherent internally and with the other EU programmes and policies. Internal coherence between fission and fusion indirect actions is ensured by supporting projects addressing topics relevant for both fields. In the Euratom Work Programme 2016-2017, the Commission included topics addressing cross-cutting issues between fission and fusion. The first topic (NFRP 13) concerned fission/fusion cross-cutting research in the area of multi-scale materials modelling, while the second (NFRP 14) aimed at cross-cutting support to improved knowledge on tritium management in fission and fusion facilities. Following the call two projects were launched in 2017, with a total Euratom support of EUR 8 million, addressing both topics (M4F – Multiscale modelling for fusion and fission materials, and TRANSAT - TRANSversal Actions for Tritium)[105].

Synergies between direct and indirect actions are ensured by participation of JRC's institutes in consortia implementing indirect actions' projects, where they provide access to research infrastructures. During the 2014-2020 Programme, JRC institutes were involved in 40 projects (41% of all), mainly concerning safety research, E&T and access to infrastructures.

Regarding coherence of the Euratom programme with other EU/Euratom programmes and policies, through cooperative research, Euratom indirect actions enable a Europe-wide approach to improving nuclear safety and radiation protection in all areas of application, which complements the implementation of the Euratom Directives on nuclear safety[106], radioactive waste management[107] and basic safety standards (BSS)[108].

As underlined by evaluations, joint programming initiatives such as EURAD and CONCERT played a particular role in this process. Effective implementation of requirements set by BSS calls for a better understanding of risks associated with exposure to ionising radiation, and Euratom-funded actions addressed this point, in particular projects PODIUM and TERRITORIES. The ongoing large RadoNorm project also plays a key role for BSS in radon exposure assessment and risk management. Euratom projects MEDIRAD, SINFONIA, and HARMONIC supported better implementation of optimisation in medical applications of ionising radiation, which is also a requirement of the BSS.

In the case of radioactive waste management, during 2014-2020, the Member States had to transpose the waste directive (directive 2011/70/EURATOM) into their national law. This directive emphasizes the importance of sustainability, holistic management of waste and spent fuel from generation to disposal and long-term safety. In each Member State, a comprehensive waste programme must be established on a solid scientific and technological basis to ensure the necessary knowledge transfer. EURAD joint programme supported Member States by defining upfront the needs for research through a consensus-based decision process, strong knowledge management and enhanced interaction between the different scientific and technical disciplines[109].

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105 European Commission, results of the 2016-2017 call for proposals.

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

107 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.

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

109 Ex-post evaluation of research for the management of radioactive waste under the Euratom Programme 2014-2020, Jean Paul Minon, 2023.

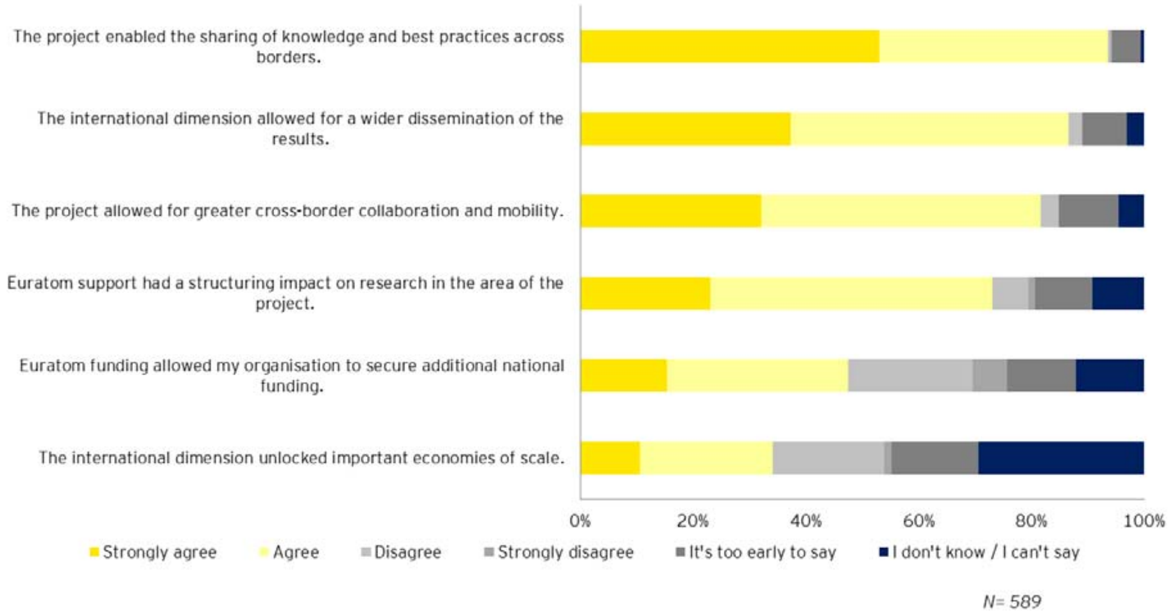
4.5. How did the EU intervention make a difference in nuclear research (EU-added value)?

A key element of the Euratom Programme added value is the ability to mobilise a wider pool of excellence, competencies and multi-disciplinarity in the nuclear research field than is possible at the level of individual Member States. Before 2014, apart from the JET exploitation and a rather small EFDA technology programme, the fusion efforts in Europe were very loosely coordinated via the so-called Bilateral Association Agreements between Euratom and the EU member states (or entities within them). From 2014 onwards the European Joint Partnership, EUROfusion, was set up and the fusion roadmap, which was developed for the first time in 2012, was used as a central element to steer towards the priorities. This has brought much more coherence to the European fusion programme. Many fusion devices, tokamak, stellarator, linear devices are now exploited by teams of scientists from all over Europe. This has for instance given advantages to small consortium members, which do not have a facility on their own, to participate in the European programme. The drawback of the European Joint Partnership, from the perspective of the consortium members, is that the administration of the fusion programme has become more complex. However, the benefit is a more coherent programme, which is on one hand competitive, but that on the other hand also has led to a situation in which most beneficiaries make best use of their expertise in a way that is complementary to that of the others[110]. This broad-based coordination at European level is of particular benefit to smaller Member States, which can take advantage of the economies of scale afforded by the Europe-wide pooling effect – in fusion research this is exemplified by smaller laboratories that can specialise in scientific topics or subsystems for fusion research facilities in Europe and make important contributions while maintaining visibility in the European consortium.

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

110 These points were underlined in specific survey filled in by EUROfusion consortium.

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



Source: Ernst & Young study

A stakeholder consultation carried out by in 2023 by the Commission, further confirmed these findings (see box below and Annex 3), showing similar replies to the same questions.

To what extent would you agree with the following statements concerning the different types of EU Added Value created by the project

The project enabled the sharing of knowledge and best practices across borders

48% Yes, very much so, **44%** yes, to a large extent **2%** No, not really **7%** don't know/no answer

The international dimension allowed for a wider dissemination of the results

35% Yes, very much so, **55%** to a large extent **5%** No, not really, **5%** don't know/no answer

The project allowed for greater cross-border collaboration and mobility

32% Yes, very much so, **51%** to a large extent **12%** No, not really, **5%** don't know/no answer

Euratom support had a structuring impact on research in the area of the project

18% Yes, very much so, **58%** to a large extent **15%** No, not really/not at all, **9%** don't know/no answer

The international dimension unlocked important economies of scale

10% Yes, very much so, **25%** to a large extent **36%** No, not really/not at all **29%** don't know/no answer

Euratom funding allowed my organisation to secure additional national funding

10% Yes, very much so, **24%** to a large extent **54%** No, not really/not at all, **12%** don't know/no answer

4.6. Is the Euratom Programme still relevant in nuclear research?

The focus of the fission part of 2014-2020 Programme on safety-related issues addressed key societal concerns regarding the use of current nuclear technology, such as operational safety of nuclear power plants and safe disposal of the most hazardous forms of radioactive waste (high-level waste and spent nuclear fuel). Nuclear safety and management of radioactive waste constituted major responsibilities at European level, with important Euratom Directives in force, and the Euratom Programme complemented this policy taking into account research agendas of technology platforms such as SNETP (Sustainable Nuclear Energy Technology Platform)[111] and IGDTP (Implementing Geological Disposal Technology Platform)[112] and of initiatives such as NUGENIA (Nuclear Generation II & III Association)[113] and radiation protection research platforms: MELODI (Multidisciplinary European Low-Dose Initiative)[114], ALLIANCE (European Radioecology Alliance)[115], NERIS (European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery)[116], EURADOS (European Radiation Dosimetry Group)[117] and EURAMED (European Alliance for Medical Radiation Protection Research)[118].

Outside the power sector, the Euratom Programme was addressing important societal concerns regarding the use of nuclear technologies in general, in particular the use of radiation in medical diagnostic and therapeutic practices. Here, the focus was on the effects of low doses of radiation on the human biota. All exposure to ionising radiation carries a potential risk and related health detriment. In normal situations, doses and therefore risks are very low, with no clinically observable tissue effects and no epidemiological evidence of any detriment. Nonetheless, risks may not always be zero, and late effects, including cancer in particular, remain possible. This calls for a multidisciplinary approach to radiation protection research, involving genomics, individual radio-sensitivity, and biological, biophysical and epidemiological aspects. This approach was at the heart of the Euratom research programme's strategy in this field. The overall approach to radiation protection has been established over many decades by the International Commission on Radiological Protection (ICRP) and is based on the ALARA principle, i.e. radiation exposures should be 'As Low As Reasonably Achievable'. The need to protect health as well as the environment is also recognised in the Euratom Treaty, in which specific provisions are laid down in Chapter III on 'Health and Safety'. In particular, Article 31 of the Treaty calls for uniform Basic Safety Standards to be established within the EU. Annex I of the Treaty clearly mentions that research on health effects is within the scope of the Community (i.e. Euratom) research and training programme.

The willingness of all national fusion labs to commit 'own resources' in the implementation of the EUROfusion joint programme indicates the attractiveness and their involvement in the Community joint effort. In total, over the period 2014-2020, 45% of the consortium's budget was to be committed from national programmes via EUROfusion beneficiaries to this joint effort. More precise figures will be known only at the end of the programme and following submission of all cost statements. At the start of the programme, and as part of the requirements for the awarding of a European Joint Programme (EJP) co-fund action Grant Agreement with the Commission, respective national fusion

111 http://www.snetp.eu/
112 http://www.igdtp.eu/
113 http://www.nugenia.org/
114 http://www.melodi-online.eu/
115 http://www.er-alliance.eu/
116 http://www.eu-neris.net/
117 http://www.eurados.org/
118 https://www.euramed.eu/

research programme 'owners' in Member States (usually at the level of ministries) signed a commitment to make national resources available for this action. Note that these resources are effectively in-kind (manpower, use of research infrastructures) and constitute about one half of the total resources of the joint programme, matched by the financial contribution from Euratom under the terms of the Grant Agreement.

5. WHAT ARE THE CONCLUSIONS AND LESSONS LEARNED?

5.1. Conclusions

Euratom-funded indirect actions achieved the general objective of the Euratom Programme 2014-2020 by supporting highly relevant research and training activities with a strong emphasis on improving nuclear safety and radiation protection. At the same time, the Programme contributed to the long-term decarbonisation of the EU energy system by providing a knowledge base and solutions to the long-term operation of existing nuclear power plants, developing fusion energy and safety case for advanced nuclear systems.

Actual performance of the Programme generally matched the expectations defined in the Euratom work programmes (calls for proposals) and grant agreements. Substantial progress is observed when considering all specific objectives for indirect actions funded by the Programme.

In nuclear safety, projects have provided relevant results and, in some cases, made significant progress concerning the original state of the art in the safety of existing NPPs and safety assessment of the generic design of advanced systems. In some cases, project stakeholders already use outputs and deliverables.

In managing spent fuel and radioactive waste, EURAD EJP and a portfolio of specific projects addressed the critical aspects of geological disposal (predisposal, safety case, construction and monitoring) and led to the deployment of joint programming to support Member States in developing and implementing their national waste management programmes.

In the area of radiation protection, the Euratom Programme 2014-2020 made substantial progress beyond the current state-of-the-art. It has significantly advanced the development of science-based evaluation of radiation risks from low doses of ionising radiation. The Programme has also played a crucial role in structuring and coordinating low dose research in Europe, launching the CONCERT European Joint Programme. These achievements underscore the Programme's commitment to pushing the boundaries of radiation protection.

In fusion research, tangible and incremental progress was made toward two specific objectives of the Euratom Programme 2014-2020: demonstrating the feasibility of fusion as a power source through successful experimental campaigns in JET and other facilities and preparing for future fusion power plants. The evaluation considered that the implementation of the roadmap has progressed successfully against its milestones and that EUROfusion consortium was deemed fit-for-purpose during 2014-2020. While the conceptual DEMO design was not completed, the technical challenges were identified, and clear research priorities were defined for the next phase.

Regarding the Programme's efficiency, the evaluation shows that most of the projects performed well in terms of producing the envisaged outputs with few significant deviations, most often arising from the natural uncertainty and unpredictability of the scientific process. Overall, it can be concluded that stakeholders view the administrative aspects of project management as burdensome but accept them as necessary for handling public money and ensuring accountability.

The Euratom programme also responded to the need to refocus fusion research, align national strategies in fission research, and build a critical mass to ensure the scale and scope required. The

Commission pushed for a greater use of joint programming and co-fund instruments to take research coordination one step further and break with the historic paradigm of project-based support under Euratom FP7. The EUROfusion consortium represented the first use of the European Joint within the Euratom Programme, followed by CONCERT in radiation protection and EURAD in waste management. This paradigm shift created much more demanding project management responsibilities than a classic collaborative project. From the perspective of the ongoing Euratom Programme 2021-2025, these three EJPs laid solid foundations for the establishment of co-funded European Partnerships in their respective fields.

The Euratom Programme tried successfully to accommodate the research needs of a vast diversity of Member States, ranging from small Member States with no civil nuclear programme and almost no nuclear research activities to large Member States meeting a large majority of their energy needs from nuclear power and on the international forefront of research. Euratom-funded calls for proposals and resulting projects provided for complementarity of the Euratom programme with national research priorities and activities. Euratom programme also played a particular role in supporting Member States' transposition and implementation of Euratom legislation in radioactive waste management and radiation protection by providing a solid scientific and technological basis for national programmes and ensuring a better understanding of risks associated with exposure to ionising radiation.

The Euratom Programme demonstrated a significant EU-added value by mobilising a broader pool of excellence, competencies, and multi-disciplinarity in nuclear research than individual Member States could achieve. Scientists across Europe collaborated on fusion devices, such as tokamaks and stellarators. Stakeholders highlighted the Programme's contributions to improving the sharing of knowledge and best practices, disseminating results internationally, fostering cross-border collaboration and mobility, and structuring research. However, the Programme's financial impact was estimated to be less significant, particularly regarding limited economies of scale and securing additional national funding.

Evaluating the Programme's efficiency and effectiveness has shown that the Commission or the beneficiaries can take some immediate action such as improvement of reporting or adjustment of work plans of existing European Joint Programmes. These will be addressed as appropriate over the coming months to optimise the Programme's implementation until its expiry by the end of 2025. Other longer-term recommendations, in particular on critical issues for the future fusion power plant and on the size and scope of fission research projects, will be further discussed during the interim evaluation exercise of the Programme 2021-2025 and the preparation of the proposal for the Euratom Programme for 2026-27. The continuous evolution of nuclear research at the EU level is necessary to ensure that it is instrumental in addressing challenges faced by all Member States in different applications of nuclear technologies.

5.2. Lessons learned

The ex-post evaluation has yielded significant evidence-based findings, highlighting key areas for improvement.

For indirect actions in fission research (nuclear safety), the evaluation suggests that efficiency could be improved by supporting larger, more integrated projects encompassing all the different issues and aspects of a particular topic, for example, the effects of ageing in reactor pressure vessels. To guarantee an adequate engineering approach and system integration, the European industry should coordinate safety projects related to developing new power reactors. Work should also continue on the integration of the research done with the support of the Euratom grants (indirect actions) with the relevant work carried out at the national level and with Euratom direct actions (carried out by the

JRC). Finally, international cooperation should be enhanced to include relevant research under the auspices of the IAEA and the OECD/NEA.

The evaluation has identified a need for improved reporting in consortia implementing Euratom-funded fission projects. Clear, concise, and factual reporting is crucial to provide a comprehensive understanding of the project's progress, achievements, and expected outcomes.

Regarding research on advanced nuclear systems, the evaluation shows that further progress in this field requires concentrating efforts and resources on the few advanced nuclear systems and applications that are really of interest to European industries.

Experts recommended that relevant non-nuclear and non-traditional partners be involved and engaged in advancing nuclear research. Examples are artificial intelligence, advanced manufacturing, 3D printing applied to nuclear technologies, integrated and hybrid energy systems, nuclear energy applications other than generating electricity like nuclear heat, hydrogen production, decarbonisation of energy-intensive industries, and nuclear desalination. Synergies between fusion and fission should be further developed, not only in the traditional area of advanced materials but also in artificial intelligence, non-power applications, advanced modelling and simulation and experimental tests.

In radiation protection, the evaluation indicates that a multidisciplinary approach in research could be further encouraged to increase coverage of a broader spectrum of scientific questions, including low-dose risks and several other questions related to planned, existing and emergency exposure situations. The radiation protection roadmap prepared by CONCERT EJP and SRA in the medical applications of ionising radiation provide a sound basis for future state-of-the-art calls and should be systematically developed.

The evaluation shows that, given the progress achieved in radioactive waste management, research should progressively depart from the acquisition of pure scientific knowledge to focus on the operation, closure, and oversight of deep geological facilities. The governance of a joint programme should integrate this evolution by reinforcing the role of waste management organisations and technical safety organisations. The ethical basis for the strategic choices made in radioactive waste management and disposal should also deserve more attention.

While the Euratom Programme made substantial progress in fusion energy, this research field is changing rapidly in recent years as international competition is increasing and a vibrant private sector is emerging globally. The evaluation shows that to proceed with the engineering design of a future fusion power plant, the Euratom Programme should focus now and in the coming few years on identifying the critical issues and risks and determining how much risk is acceptable. Innovation will then be needed to address critical enabling technologies for fusion energy and to mitigate related risks. While the Programme helped make substantial progress in understanding plasma physics for ITER and beyond, there is a need to develop computational tools to predict, analyse, and interpret experimental results further. A future fusion power plant also requires efficient project engineering. While this element is expected to be delivered by industry, Euratom-funded actions could include a project engineering and management training scheme combined with specialised fusion knowledge.

ANNEX I. PROCEDURAL INFORMATION

1. Lead Directorate-General (DG): DG Research and Innovation
2. Decide reference: PLAN/2022/2284
3. Euratom Work Programme (financing decision for contracting experts): C(2022) 4240
4. Exceptions from the better regulation Guidelines:

   Rationale for targeted stakeholder consultation – the Commission carried out a targeted consultation in different format for fission and fusion research. For fission research (nuclear safety, radioactive waste management and radiation protection), consultation was carried out on the basis EU Survey questionnaire sent to the persons involved in 2014-2020 Euratom projects. For fusion research, a questionnaire about scientific achievements and implementation was completed on behalf of EUROfusion consortium (ca. 200 members) by the EUROfusion Programme Management Unit. In addition, for both research fields we used findings from the survey and interviews carried out carried by Ernst & Young for the interim evaluation. While the Euratom questionnaires covered all aspects required by the Better Regulation for public consultations, use of a targeted consultations in different formats allowed to expand section of the questionnaire on scientific/technical aspects of the Programme. Stakeholder consultation served also as a call for evidence. A questionnaire filled in by the EUROfusion consortium provided a wealth of data on different aspects of the fusion energy research funded by Euratom (accounting for 2/3 of budget for indirect actions).

5. Organisation and timing:

   Start of evaluation work by Commission services: September 2022

   Stakeholder consultation: December 2022 - April 2023

   Appointment of independent experts: November 2022

   Delivery of reports by experts: May 2023

   Interservice Steering Group (composed of representatives from ENER, JRC, SG, SJ) provided written comments on the SWD in January and June 2024.

   Finalisation of SWD and launch of Inter-Service Consultation: July/August 2024

6. Consultation of the Regulatory Scrutiny Board (RSB):

   Evaluation of the Euratom Programme 2014-2020 was not selected for assessment by RSB.

7. Evidence used for evaluation:

   The evaluation was based on the following sources:

   - Statistics on the implementation and results of Euratom calls for proposals launched during 2014-2020 (Commission CORDIS database https://cordis.europa.eu/);
   - Periodic and final reports from Euratom projects funded under 2014-2020 Programme (available in Commission CORDIS database https://cordis.europa.eu/);
   - Deliverables from projects funded under 2014-2020 Programme (available to Commission services and independent experts);
   - Questionnaire on scientific achievements and implementation submitted by EUROfusion consortium (April 2023)
   - EC assessment of EUROfusion annual reports (2014-2020)

- DEMO Gate Review Panel report (https://euro-fusion.org/eurofusion-news/expert-panel-demo-design/)
- Articles from peer reviewed journals covering different aspects of research carried out by EUROfusion (for details see table 16 in section 3)
- Commission Staff Working Document SWD(2013) 213 'Towards a Modern Euratom Fusion Research Programme
- Thematic reports by external experts and studies prepared by contractor (see section below)

8. External expertise

Major part of the ex-post evaluation is based on the assessment made by external experts, who evaluated progress made and impacts on the basis of evidence from Euratom-funded projects and interviews with project coordinators.

To prepare Staff Working Document, the Commission services used thematic reports prepared by experts appointed in Autumn 2022 following a call for expression of interest:

- Helena Janžekovič (inspector at Slovenian Nuclear Safety Administration) - report on ex-post evaluation of indirect actions in Radiation Protection under the Euratom Research and Training Programme 2014-2020, May 2023
- Jean-Paul Minon (former CEO of ONDRAF/NIRAS, Belgian radioactive waste management authority) - report on ex-post evaluation of research for the management of radioactive waste under Euratom Programme 2014-2020, April 2023
- Dr. Eng. Stefano Monti (former Head of the Nuclear Power Technology Development Section of the International Atomic Energy Agency, report on ex-post evaluation of indirect actions for reactor safety under Euratom Research and Training Programme 2014-2020, April 2023
- Professor Steven Cowley (Director of Princeton Plasma Physics Laboratory and Princeton University), report on ex-post evaluation of indirect actions in fusion research and development under Euratom Research and Training Programme 2014-2020, March 2023

When preparing this evaluation, the Commission also used findings of two studies prepared by Ernst & Young consultancy for the interim evaluation of the Programme.

- Study on the evaluation of the management and impacts of fusion and fission research supported by the Euratom Research and Training Programme 2014-2018 and previous Euratom Programmes

- Study on the Management & Governance Assessment of EUROfusion

Reports and studies are available at https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/euratom-research-and-training-programme_en

ANNEX II. METHODOLOGY AND ANALYTICAL MODELS USED

Assessment of the Euratom Programme followed the Better Regulation guidelines for evaluation of EU actions with particular focus on elements specific for research programmes.

Section 2 on expected outcomes of the Programme was prepared on the basis of impact assessment and explanatory memorandum accompanying the Commission proposals for the 2014-2018 and 2019-2020 Programmes. It explains the intervention logic by providing a brief description of the problems and needs the Programme was intended to solve. It also provides description of how the Programme fitted in the wider policy framework in the past. For fusion research, description of the rationale for transition of research organisation relies on the Commission Staff Working Document SWD(2013) 213 'Towards a Modern Euratom Fusion Research Programme which supplemented the Commission proposal in this respect. The subsection on points of comparison provides a brief description of the expected achievements in terms of outputs, results and impacts prepared on the basis of work programmes, EJPs work plans and description of work attached to the grant agreements.

Section 3 on how the situation has evolved over 2014-2020 describe how the Programme was implemented, what has happened in quantitative and qualitative terms using data from the calls for proposals, Key Performance Indicators, outcomes from projects such as publications and data on participation in Euratom-funded projects.

Section 4 on evaluation findings explains in detail if the specific objectives of the Programme were achieved in terms of scientific progress and evolution of research organisation with particular focus on the European Joint Programmes. Each thematic subsection (fission and fusion research) is based on findings from 4 specific reports prepared by external experts, triangulated with additional sources such as Commission's Project Officer reports, peer review articles summarising progress in specific field, mid-term or final evaluation reports by external experts requested by the Commission for specific projects. Where relevant these findings are supplemented by observations from the stakeholder consultation. Implementation of the novel organisation of research, European Joint Programmes is discussed in detail on the basis of E&Y study (focused on EUROfusion), and to lesser degree on the basis of study on radioactive waste management where EURAD EJP was analysed.

Limits of the evaluation – ex-post evaluation provides a picture of research activities funded by the Programme and estimates their results and impacts. Impact is usually a long-term result, and it is usually not achievable during the life cycle of the project. Indeed, more often, the impact of Euratom projects must be viewed within the context of previous (FP7) and future research efforts (on-going 2021-2025 Programme), which will only deliver tangible results in the longer-term. Moreover, the ultimate impact is often influenced by a number of other factors external to the project, which may either contribute to or detract from the impact of a specific project. The impact for many projects appears clear but is often less tangible and difficult to measure. Indeed, one of the most significant types of impacts appears to be the development of new knowledge in the various fields covered by the Euratom projects. This impact is often difficult to quantify but can be appreciated by considering the long-term development of the state-of-the-art in the field of study.

Authors of the thematic evaluation studies, in particular in nuclear safety, indicated that the task to analyse results and impacts of the Euratom-funded projects was particularly challenging. The main reason is that most of the progress reports and other available material instead of providing a gap analysis, a self-evaluation of the results and achievements and some elaboration on the possible outcomes (i.e. expected impacts), they just repeat the goal and objectives of the project and describe – sometimes also with excessive details – the managerial activities carried out during the project and the events organized by the project team. Only a few reports provide detailed description of and discussion on the technical results and also in these cases it is hard to understand the real progress with respect to the pre-existing state of the art and whether the project provides added value. Finally, only for a few projects there is evidence of some feedback from final users and beneficiaries of the results of the project; this makes evaluation of possible longer-term impact pretty challenging. Whenever possible, evaluators studied also projects' deliverables, in particular if they were in report form.

ANNEX III. EVALUATION MATRIX

Evaluation criteria	Evaluation questions	Data sources	Success criteria – points of comparison	Indicators per success criterion
Effectiveness/Efficiency (Section 4.1)	Did EUROfusion research 2014-2020 extend the basis of ITER-relevant fusion science to ensure that future ITER operation will be effective and efficient?	– Independent expert assessment of progress made by EUROfusion – Targeted consultation (EUROfusion questionnaire) and EUROfusion Annual reports – Peer-reviewed publications databases	Development and qualification of plasma regimes of operation for ITER	- Successful JET experimental campaigns - Predictive simulation tools that have been validated against experimental results across Europe
	Did EUROfusion make substantial progress in laying the foundations for future fusion power plants by developing materials, technologies and conceptual design?	– Independent expert assessment of progress made by EUROfusion – DEMO G1 Gate Review Panel Report – Targeted consultation (EUROfusion questionnaire) – EUROfusion annual reporting and EC assessment – Peer-reviewed publications	Progress in developing materials, technologies and conceptual design for future fusion power plant	- Candidate materials have been selected for all components of future fusion reactors - Design of IFMIF-DONES neutron source has been developed - Two tritium breeding blanket concepts prepared by EUROfusion for absorbing neutrons from fusion reactions and for breeding tritium fuel are well advanced - Advanced engineering work for the DEMO pre-conceptual design
	Did the EUROfusion actions for training the next generation of scientists and engineers provide sufficient basis for future implementation of the European Fusion Programme?	– Individual expert report on progress made by EUROfusion – Targeted consultation (EUROfusion questionnaire) – EUROfusion HR survey	Training of fusion MSc, PhD and post-doc fellows in the domains needed for the effective implementation of the fusion research	- Increase of PhD students per year from 675 (2014) to 734 (2020); - Increase of Engineering and Researcher Grants from 17 per year (2014) to 34 per year - Female level increase from 18% (2014) to 21% (2020)
Relevance (Section 4.5)	Do the Euratom programme 2014-2020 objectives still reflect current and for the development of fusion energy	– Independent assessment by experts – ITER International Organisation Council documents – Financial data from implementation of projects	- The willingness of the Euratom Programme's beneficiaries to commit 'own resources' in projects and EJPs indicates the	- Beneficiaries' co-funding ratio for European Joint Programmes (ca. 40-45%), and for collaborative projects (25%). - 63% of fission research projects in

		(CORDIS) – Opinions of the Euratom Scientific and Technical Committee – Stakeholder consultations (2017 & 2023)	attractiveness and relevance of the Programme - High relevance of Euratom funded projects for nuclear safety - Confirmation of relevance of the Euratom research actions by independent advisory committees and organisations. - Continuous update of research roadmaps by Euratom co-funded European Joint Programmes	nuclear safety were assessed as fully relevant for the Programme's objectives. - ITER Council documents confirming relevance of EUROfusion experiments for ITER (IC/STAC-23/3.1 – Report on ITER Organization strategy and progress in resolution of issues on the Disruption Mitigation System and VDEs); - Positive opinion of STC on relevance of 2014-2020 Euratom research in fusion (STC-2018-06) and fission (STC-2018-10); - 2017 update of the EUROfusion research roadmap.
Coherence (Section 4.3)	Is the Euratom Programme coherent internally (direct and indirect actions, fission and fusion research) and externally (supporting implementation of Euratom legislation, complementing national programmes)?	– Euratom Work Programmes 2014-2020 – Data from implementation of projects (CORDIS) – Thematic evaluation of fission projects by experts – Stakeholder consultation – Research roadmaps established by Euratom-funded European Joint Programmes (radiation protection, radioactive waste management, fusion research)	– Substantial participation of JRC in indirect actions (projects) – Increase in number of actions addressing topics relevant for fission and fusion research – Positive opinion of the Programme Committee (Member States) on the Euratom Work Programmes (calls for proposals) – Support for implementation of Euratom directives (nuclear safety, radioactive waste management, basic safety standards – Positive perception of the Programme's alignment by the stakeholders. – Agreement on research	- During 2014-2020 Programme, JRC institutes participated in 40 projects (41%). - Two projects funded with 8 million Euro (M4F, TRANSAT) - 7 Commission proposals for Euratom Work Programmes (4 main WPs plus 3 amendments) supported unanimously by the Member States in the Programme Committee. - 18 (19 %) projects contain references to Euratom directives (BSS/Safety Directive/RWM Directive). - Respondents confirmed the alignment of Euratom actions with national research priorities and relevance of the Programme in general in the stakeholder consultation (questions 22 and 23) - Agreement on 3 research roadmaps by European Joint Programmes for

			roadmaps by Euratom co-funded European Joint Programmes	research on radiation protection, radioactive waste management and fusion energy.
EU added Value (section 4.4.)	How did the Euratom Programme 2014-2020 make difference for the participants?	– Stakeholder consultation (2017 and 2023) – Questionnaire from EUROfusion – Thematic reports from independent experts	– Positive perception of added value by stakeholders. – Positive trend in evolution of stakeholder perception (from the mid-term to the end of the Programme) – Increase in the joint exploitation by pan-European teams of research facilities	- Respondents confirmed the EU-added value in 5 out of 6 categories. For the details, see section 4.4 and Annex V – question 23. - Comparable results of stakeholder consultation in 2017 and 2023 - Increase in the number of researchers participating in joint exploitation of research facilities: from 872 (2014) to 1734 (2020)

ANNEX IV. OVERVIEW OF BENEFITS AND COSTS

Benefits of Euratom Programme 2014-2020

Euratom Programme gives rise to a range of benefits, presented in Section 4.1 (Effectiveness) in the context of the nuclear fission and fusion research. In the framework of Better Regulation this means Euratom programme generates:

1. Indirect long-term welfare benefits for EU society derived from scientific impact, and related benefits for participants

The R&I framework programmes, including Horizon 2020 and Euratom, **support activities that generate scientific outputs** (e.g. scientific publications) **and outcomes/results** (e.g. positive effects on researcher careers after participation), which are **direct and indirect benefits for its participants**. Some of the direct outputs of Euratom programme have been quantified and are summarised below..

In the long run, these effects on beneficiaries have a strong potential to lead to **indirect welfare benefits for EU society**, i.e. to positive social, environmental, or economic impacts from scientific progress (e.g. improvements in public health due to better cancer treatment based on radiotherapies, clean air due to longer term operation of Nuclear Power plants). These potential long-run benefits have not been systematically assessed. Other Euratom's future long-term welfare benefits (from fusion research for example) are difficult to predict and may arise in yet unknown areas (in particular if on-going research will prove feasibility of fusion as energy source). The links between past R&I support programmes and currently observable welfare improvements from scientific progress are not systematically monitored. In addition, many external factors contribute to any scientific breakthrough or advancement, which makes it difficult to establish a causal link with specific instances of R&I funding.

2. Indirect wider economic benefits for EU society from diffusion of innovation, and related economic benefits for participants

Euratom Programme supported research and innovation in broad number of applications of ionising radiation (power and non-power), which had the aim to improve safety of these applications as well innovation diffusion in products, processes, and services. The related **innovation outputs** (e.g safety improvements, new cancer treatments, safe radioactive waste treatment and long term storage) and resulting economic **outcomes/results** (e.g. improved economic performance of firm after participation) constitute **direct and indirect economic benefits for private sector participants**.

Euratom Programme supports research activities focused on tackling **societal challenges.** Some activities on societal challenges are geared towards generating **positive direct, non-market effects**, such as informing the policy debate, which are expected to contribute to **indirect, non-monetary social and environmental benefits** *(*e.g. positive impacts on Europe's security and safety), thus **increasing the welfare of**

society in the long run. Although it is considered likely that at least some of these benefits have materialised, they have not been systematically assessed by the evaluation, due to the lack of a monitoring and evaluation framework.

Costs of Euratom Research and Training Programme 2014-2020

In line with the Council regulation establishing the Euratom Programme (Article 7(1)), the Programme was implemented on the basis of Horizon 2020 rules of participation. Therefore evaluation of the costs for beneficiaries and applicants is based on findings of the relevant Horizon 2020's studies.

The Euratom Programme has given rise to four main types of costs incurred by different stakeholder groups, which also influence its efficiency:

1. Euratom's operational expenditure - is the main direct cost of the Euratom programme. It is incurred by EU society and constitutes the input that enables the R&I activities and leads to the generation of benefits to society. The money is invested through calls and other activities (e.g., events, studies) and comes out of the programme's voted budget. (Reported below in Table 1, II. Costs)

2. Administrative Cost of the European Public Sector – are funded separately through the Union's budget as Euratom Programme's **Administrative Expenditure**. This cost of administrating and running the Euratom programme is borne by the **public sector at European level**[119] (and ultimately EU society) and is the second main cost factor that affects its overall efficiency. (Reported below in Table 1, II. Costs)

Evidence collected on the **cost of the proposal evaluation process** (included in the total administrative cost) suggests that an average public sector time cost[120] for the evaluation of one proposal to arrive at ca. 58.6 hours (single stage process) of evaluation expert time. An approximate monetised value of the evaluation of one proposal was estimated[121] to about **€ 3 300** (single stage process), excluding administrative costs of organising the evaluation, based on the pay rate[122] of an evaluation expert.

3. Administrative costs of Euratom beneficiaries (non-additional, compensated for in operational expenditure) - the 796 participants[123] of Euratom Programme 2014-2020 spent substantial effort on the actual research and innovation activities, which generated the benefits, reported

119 Public sector administrative costs related to the FP at a national, regional, and local level are not covered in the evaluation.
120 Study on the proposal evaluation system for the EU R&I framework programme. Annex (2022), p. 152.
121 Horizon 2020's Evaluation support study on Resilient Europe; Annex1 Section 5, Table 60, p. 122.
122 The Euratom and Horizon 2020 Model Contract for Experts indicates that the expert is entitled to a fee of EUR 450 for each full day worked in accordance with Article 3(2). Calculation assumes 8-hour day. (https://ec.europa.eu/research/participants/data/ref/h2020/experts_manual/h2020-experts-mono-contract_v1.1_en.pdf).
123 Corda dashboard data: Unique participants in signed grants, as of 1/1/2023.

under effectiveness. In addition, participants also incurred costs (i.e. spent effort, money and time) to fulfil **Euratom's administrative requirements** for each of their 1873 participations[124]. These **administrative costs of programme beneficiaries**, while to an extent operationally unavoidable, are not directly productive in terms of benefits. They have the potential to introduce substantial inefficiencies into R&I support. Reducing the administrative costs of beneficiaries was one of the aims of the simplification measures of Horizon 2020 and consequently also of Euratom Programe (see section 4.2.2)

In the **public consultation** (Note - for Horizon 2020, however these findings are applicable to Euratom Programme as well due to the same rules and instruments), the majority of respondents stated that **the effort needed to participate in Horizon 2020 was 'similar' (39%; 692 respondents), or even 'greater' (17%; 303) compared to that under FP7**. Only a minority of respondents (**12%; 219**) **spent less effort** (with one-third of the respondents not providing an opinion). Although exact percentages differed, the overall pattern of the feedback matched that of responding EU citizens (34% similar, 13% greater, 9% lower effort) and was influenced by responses from **academic and research institutions** (41% similar, 21% greater, 12% lower effort), with over 190 respondents (over one-fifth) of this stakeholder group reporting a cost increase relative to FP7. Improvements seem to have been slightly more pronounced for the private sector, according to responses from **business associations** (44% similar, 16% greater, 28% lower effort) and **companies/business organisations** (40% similar, 12% greater, 14% lower effort).

Around 300 respondents provided information on the **time cost to manage participation** in terms of the '**average number of person-days**[125] spent during the entire project', which allows for some very approximate quantification. As expected, projects of longer duration (average for Euratom is 47 months) experienced higher total administrative time costs, 48-month (332 person-days) long projects showed **high average administrative time costs** of **6 to 7 person-days per month**.

Expressing the average value of 7 person-days/month, as order of magnitude money values, would imply that the total beneficiaries' administrative cost of Euratom amounted around EUR 20 million[126].

The uncertainty the respondents' interpretation of the question, the non-representative nature of the public consultation as such, and the small sample of respondents overall means that there is a **very high level of uncertainty around the (time) cost values representing beneficiaries' administrative costs of participating in Euratom Programme. The presented values are insufficiently robust to inform programme design**.

[124] Corda dashboard data: Participations in signed grants, as of 1/1 2023.
[125] I.e. expressed in multiples of working days of one person.
[126] This monetisation uses the programme's total number of project months (4969 months) and is based on the wage tariffs of Better Regulation Tool 58

4. Costs of applicants - Successful and unsuccessful applicants to the Euratom programme incur a one-off cost: they invest effort, time, and money to prepare proposals. Application costs are mainly determined by the specific requirements of the programme and rise with an increase in competition between applicants. For an evaluation, from the point of view of EU society, these application costs are relevant. They have the potential to introduce substantial external inefficiencies into the R&I support, as time, effort, and money spent by unsuccessful applicants can, to a great extent, become a deadweight loss to society unless captured suggests otherwise. High application costs also drive away potential applicants and so have the potential to distort the participation of applicants with respect to relevant characteristics, such as capital constraint, lack of experience, and the availability of outside options of funding to the applicant.

How high were the costs of applicants?

The Horizon 2020 evaluation has brought together around 40 individual instances of evidence of variable but generally low levels of robustness on the actual cost of application. The cost data received suggest that actual costs seem to **vary widely by funding instrument**. They are also **influenced by the evaluation process and type of stakeholder group** targeted. **The information available is of insufficient quality to generate a robust aggregated cost of applicants for the programme. It nevertheless illustrates the order of magnitude of the costs of preparing a proposal**.

In the context of several support studies, the Horizon 2020 evaluation collected some evidence from beneficiaries on costs of applications[127] expressed in money terms. The **average cost of one proposal for Horizon 2020 was estimated[128] to fall into the range of €18 000 to €37 000**. We use these findings for evaluation of Euratom Programme 2014-2020.

This suggests that the **application costs of beneficiaries** alone, who submitted 98[129] successful proposals, would amount to between **€1.8 million and €3.6 million**. This value is rendered very uncertain by the lack of adequate, systematically collected evidence and should be read as a **rough illustrative figure only**.

Unsuccessful proposals[130] (162 for 2014-2020 Programme) did not directly lead to productive outputs under Euratom Programme but also cost effort and money to prepare. Unsuccessful applicants are a stakeholder group the evaluation has not systematically consulted. Due to a severe lack of robust evidence the estimation of this cost has to rely on strong simplifying assumptions. Given the average costs of proposal above, the

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[127] Although the evidence predominantly stems from beneficiaries, success is not assumed to be generally correlated with application costs across the FP, although it likely has some influence at the margin.

[128] Evaluation study on Resilient Europe estimated a range between €20 000 and €34 000 and the evaluation study Excellent Science €18 257 to €37 169 for one proposal.

[129] Dashboard, Horizon 2020, 'Retained Proposals' as of 01.01.2023

[130] Unsuccessful proposals here include all proposals, which are effectively unsuccessful as they do not lead to any funding under Horizon 2020, including those of high quality.

total costs for unsuccessful proposals is estimated at between **€3 million and €6 million**. Evaluations of earlier programmes did not report estimates that could be used as direct points of comparison..

Public Consultation (for Horizon 2020) responses provide basic **time cost ranges[131]** and show a pattern of diminishing proportions of applications as application time costs rise: Responses suggests that **56% of applications take less than 50 person-days, with 80% of applications under 100 person-days**. The study on the proposal evaluation system[132] finds that the average time spent by 'applicants' [133] on a **single-stage application was 25 person-days.**

What does the oversubscription and success rate mean for the efficiency of Euratom Programme?

Compared to Horizon 2020, the success rate for Euratom Programmew 2014-2020 was much higher 37,6% (96 successful proposals for 255 aplications). In principle, oversubscription of an individual programme part primarily indicates where the resource constraint of the budget is particularly binding. The competition between applicants depends to some extent on the oversubscription of a programme, which in turn increases the likelihood that the eventually funded projects are of good quality and generate benefits and value-for-money.

Were application costs 'proportionate' for applicants, taking into account the potential benefits?

The level of oversubscription of Euratom programme suggests that up front, at the time the decision is made, the programme is relevant and attractive enough for a large number of potential applicants to go ahead and invest effort.

At the level of the Euratom programme (indirect actions), in relation to the € 1094 million of R&I support, applicants spent an indicative total of € 5 million (**approx. 0.5%)** to € 10 million (**approx. 0.9%)** of application costs. The main reason for substantial difference between Euratom and Horizon 2020 is much higher success rate for Euratom Programme). Given the insufficient level of confidence in the cost estimates it is not possible to base any firm conclusions on these values and it is a topic for further discussion, what percentage would still be acceptable and constitute 'proportionate' costs. Taken together, the available information is, however, sufficient to suggest that it cannot be ruled out that disproportionate application costs may have been an issue in Euratom/ Horizon 2020, particularly in some areas of the framework programme, possibly also at an aggregate level. The question of proportionality of application costs of R&I support therefore deserves continued attention.

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131 Annex 5: Cost of proposal preparation, p. 94.

132 Study on the Proposal Evaluation System for the EU R&I framework programme, 2022, Table p. 3, https://data.europa.eu/doi/10.2777/16211.

133 No further breakdown was reported for the question; however, beneficiaries dominate responses. The time cost of the multi-stage application captures the higher time cost of successful applicants. The vast majority of (unsuccessful) applicants only incur costs for the simplified first application stage. The overall average may therefore be expected to be at least equal if not lower than for a single stage procedure.

Annex IV Table 1

Table 1. Overview of costs and benefits identified in the evaluation

		Citizens/ EU Society		EU Public Administration		Euratom Beneficiaries		Euratom Applicants	
		Quantitative	Comment	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment
I. BENEFITS									
1. Indirect long-term welfare benefits for EU society from scientific impact	one off	(No estimate available)	Euratom strengthened nuclear research, contributed to scientific breakthroughs and advancements. It increased the human capital of researchers through furthering EU-wide career development and access to research infrastructures. In the long run, the supported activities are expected to lead to sizable and wide-ranging welfare benefits to EU society (economic, social, and environmental benefits).			1. Peer-reviewed publications 6166 2. Researchers undertaking cross-sector and cross-country mobility, 3632 3. No. researchers who gained access to research infrastructures 1734	Direct scientific output of Euratom (benefit to researcher) linked to expected long-term welfare benefits from scientific impact (Number as of 24/04/2023)		
II. COSTS									

		Citizens/ EU Society		EU Public Administration		Euratom Beneficiaries		Euratom Applicants	
		Quantitative	Comment	Quantitative	Comment	Quantitative	Comment	Quantitative	Comme nt
1. Direct economic cost of R&I funding to EU society (Operational Expenditure)	one off	€ 1509 million	Operational Expenditure of Euratom						
2. Administrative costs of implementing the R&I framework programme to EU Public Sector (Administrative Expenditure)	one off		Costs of administrating Euratom are incurred by the public sector at European level but are ultimately a cost on EU Society.	€ 95 mio	Administrative Expenditure of Euratom programme (indirect actions) Administrative expenditure as share of budget envelope 6,16%				
3. Beneficiaries' administrative costs of participation (Not additional - already included in no.1 Operational Expenditure)	one off					Time cost: on average 7 person-days per month of project duration € 20 million – Note: evidence not robust. Particularly upper bound value may be substantially higher as projects of 60 months and	Administrative costs per participation incurred to meet requirements (e.g. reporting). Monetised order-of-magnitude estimate: Administrative costs of beneficiaries		

						more exceed 10 person-day per project months.			
4. Costs of applications Direct costs of preparing proposals of successful and unsuccessful applicants	one off							€18 000 to €37 000 (evidence not robust) Successful: €1.8 million to €3.6 million Unsuccessful: € 3 million to 6 million	Cost per proposal (evidence not robust) Total cost of applications (evidence not robust)

Simplification measures - additional information on performance

Expectations - simplification in the Euratom Programme and Horizon 2020

‘Simplification’ was a central to Horizon 2020 and consequently to the Euratom Programme which shared the same rules and instruments. Efforts to simplify the programme influenced its design, its rules, financial management, and its implementation. The ambition was comprehensive, and expectations were clearly expressed. The European Parliament[134] and the European Council[135] had called to radically simplify access, to simplify to boost the attractiveness and lower the associated burden of EU research funding. The ‘radical overhaul’ of the administration of FP was seen as the highest priority to be tackled. The 2011 ‘Green Paper on a Common Strategic Framework for EU Research and Innovation Funding’ picked up on these findings and requests. It identified simplification as a ‘top priority’ in order to make EU research and innovation funding generate more impact and be more attractive to participants; it also prompted to simplifying participation by lowering administrative burden, reducing time to grant and time to payment, as well as achieving a better balance between cost and trust based approaches.[136]

In consequence, Euratom and Horizon 2020 substantially changed the set-up and management of R&I support. Previous expectations were repeated in the Regulation establishing the Euratom programme, which explicitly introduced ‘simplification’ as a central aim[137]. Simpler funding rules were expected to reduce the administrative costs of participation and to contribute to the prevention and reduction of financial errors[138].

Euratom Programme’s performance against time cost targets

The quantitative administrative target on time to grant shines a spotlight on one specific aspects of administrative efficiency. Euratom and Horizon 2020’s binding TTG target of 8 months (245 days) per call was more stringent than FP7’s previous TTG target of 270 days. An overview over targets and actual achieved values for Euratom/Horizon 2020 and FP7 are summarised in Table 12.

134 ‘Simplifying the implementation of the research framework programmes’, European Parliament resolution of 11 November 2010 on simplifying the implementation of the Research Framework Programmes (2010/2079(INI)).
135 Council conclusions on Europe 2020 flagship initiative: Innovation Union. 26.11.2010.
136 GREEN PAPER From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation funding (COM(2011) 48 final).
137 Ambition outlined in Recital 20 and 24 in the Euratom regulation.
138 Ibid.

Table 1: Actual Time-to-grant (TTG)

Programme	FP7	Euratom 2014-2020
Target [avg. days]	270 days	245 days
Actual TTG [avg. days]	313 (41%)	238

Potential for further simplification - additional information

Adaptation costs linked to changes to programme design, rules and procedures, including simplification measures

The evaluation found that the complexity of the Euratom programme overall has remained persistently high, resulting in a burden for applicants and beneficiaries. A potential for the reduction of this burden therefore does not only stem from the characteristics of any new design, rules or processes as such (i.e. costs of a new steady state) but also from the transition period during which the changes are designed, tested, announced, introduced and rolled out. The 2018 ECA report[139] highlighted the (one off) **adaptation costs for beneficiaries from any changes to the programme** and the associated **legal uncertainty,** where changes occurred in too quick succession**.** Participants have to inform themselves about updates, interpret the changes, establish with certainty which rules apply to them at a given time and then adjust. The report therefore emphasised **the importance of stable and well-designed rules to minimise participants' administrative costs**. This implies that, even where

139 Court of Auditors. Special Report. N.28 (2018) - Concretely, the report pointed at the introduction of simplified rules on personnel costs, which had to be adjusted again shortly after in response to negative side-effects that had emerged, leading to 'confusion and legal uncertainty'.

beneficiaries’ administrative costs or application costs would be lower once simplification measures have taken hold, the transition process is costly and can cancel out at least some of these positive effects. This suggests that **infrequent, carefully designed and piloted step-wise adjustments**, which pay close attention to **the participants’ perspective** and are accompanied by **clear communication measures and *ex post* assessments** can have a simplification potential in of themselves.

Similarly to Horizon 2020, the Euratom programme strives to be as simple and efficient as possible. It falls under the Regulatory Fitness Programme (REFIT) of the European Commission, seeking opportunities to simplify and reduce administrative burden for people, businesses and administrations. The Horizon 2020 introduced two main strands of simplification measures:

- **Structural simplification and a general overhaul of implementation processes**, that had primarily the objective to 1) lower the direct administrative cost of applicants and beneficiaries that are associated with participating in Horizon 2020, and 2) increase the EU public sector’s efficiency of administering the framework programme through accelerating all processes relating to proposal and grant management,
    - **Simpler funding rules and a revised ‘control and risk strategy’.** These measures primarily set out to optimise the balance between the administrative costs of beneficiaries and the benefits of reducing financial errors.

Time to grant – any potential for further simplification?

The average time-to-grant values reported outperform the targets across the programme (see Annex IV.3 above). At a first glance, a further tightening of the targets could hold further potential for simplification. However, like every target, the time to grant target is an imperfect proxy, in this case for the efficiency of activities related to the evaluation of grants and the preparation of the grant agreement. The setting (or tightening) of the target -without any accompanying measure that would make such a change plausible- is associated with the risk of generating (or increasing) negative unintended consequences, particularly when other connected administrative processes are changed at the same time. A shorter time span for grant preparation is associated with an increase in risk of errors. Considering the already material error rates of the programme, any such increase in risk would not be welcome. Furthermore, while an increased use of lump sum funding is expected to keep financial error rates in check, it will simultaneously shift some of the burden of financial checks from the reporting stage to the evaluation (of the proposed lump sums) of proposals. This will potentially reduce again the current scope to further tighten the time-to-grant target. Once a wider use of lump sums has been established, a new assessment of the performance against the target can be carried out to assess any room for manoeuvre. The evaluation therefore finds that it is not recommendable to incentivise a further shortening of the time-to-grant period until the effects of lump sum funding on the timing of the proposal evaluation and on the resulting error rate can be established.

TABLE 2: Simplification achieved and further potential
PART I: Simplification and burden reduction (savings already achieved)
Simplification, burden reduction and cost savings **achieved already** by Horizon 2020, including points of comparison where available.

	Citizens/ EU Society		EU Public Administration		Euratom Beneficiaries		Euratom Applicants	
	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment
Administrative cost savings of the EU public service (costs associated with administering the framework programme) through accelerating all processes relating to proposal and grant management. The evaluation found that the introduction of the **electronic grant management workflow** and the **withdrawal of the negotiation stage** were key drivers of the acceleration								
One-off (change from FP7 to Horizon 2020)			Time-To-Grant (TTG) reduction Euratom Programme saved over **20 years of time** in the EU public sector, relative to what it would have taken at the speed of FP7. Euratom programme 2014-2020: **saving of 75 days per grant** on average vs. FP7.	Time cost saving for public sector **from accelerated administrative processes** (from end of deadline for proposals to grant agreement signature) Key drivers: - electronic grant management workflow; - removal of negotiation stage.	Start dates of beneficiaries' projects brought forward in total by over 20 years of time. **.**	**Time cost saving for beneficiaries** from accelerated administrative processes.		

PART II: <u>Potential</u> simplification and burden reduction (savings) Identified further potential simplification and savings **that could be achieved** with a view to make the initiative more effective and efficient without prejudice to its policy objectives[140].								
	Citizens/ EU Society		EU Public Administration		Euratom Beneficiaries		Euratom Applicants	
	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment
Application of unsuccessful applicants are an area with a potential for efficiency savings for the framework programme. The evidence base of the evaluation does not allow to specify any new simplification measures to the extent, that they could be assessed in terms of their expected costs savings'. Potential existing measures that could be extended include: a targeted, carefully tested and designed use of the **two-stage evaluation processes**; and any measures that prevent the loss of the value inherent in successful-unfunded proposals (proposals above the quality threshold but that remained unfunded due to the budget constraint) and allow it to be captured for alternative funding applications at EU or national level. This may include the Seal of Excellence measure, after a detailed *ex ante* assessment.								
One-off			n/a	Public sector administrative expenditure related to proposal evaluation costs are an area with a potential for efficiency savings, to the extent that a duplication of an evaluation can be avoided.			n/a	Application costs of unfunded proposals are an area with a potential for efficiency savings for the framework programme overall.
Lump sum funding involves the paying out of pre-agreed lump sums (that were specified in the proposal by the grant beneficiary) after the completion of a work package. It renders obsolete the financial reporting (by beneficiary) and the checking of financial reports, as well as the reimbursement of detailed eligible costs by the EU public administration).The evaluation of the lump sum pilot suggests that a wider use of lump sum funding likely has some simplification potential to reduce <u>beneficiaries' administrative costs</u> and address the persistence of frequent <u>financial errors</u>, highlighted by the European Court of Auditors. The net effect on costs depends on details of implementation.								
One-off	n/a	The use of lump sums has the potential to reduce financial errors by	n/a	Public sector administrative expenditure is expected to change	n/a	The use of lump sums has potential to reduce the net administrative costs	n/a	Application costs may increase, as proposals have to submit an additional budget table

		removing financial reporting and the reimbursement on the basis of eligible costs (both sources of financial errors in R&I funding). The extent to which a reduction of errors can be achieved, and a reduction of the error rate can be observed, depends on details of implementation, including that of *ex post* project reviews and any changes to the audit strategy. While the rationale of lump sum funding supports the assumption that financial errors will overall be reduced, the piloted projects have not yet generated any *ex post* evidence to allow for a validation of this assumption and an *ex ante* estimation of future simplification effects.		due to multiple factors. The direction of the net effect on public sector costs depends on implementation details that determine the additional workload of proposal evaluators and possible adjustment costs for project officers. The net effect will also be affected by beneficiaries' strategic behaviour (unintended effects) in response to the measure over the medium-term. The currently available evidence base is insufficient to assess the direction or magnitude of the net effect on public sector administrative costs.		of beneficiaries, who no longer have to report on eligible costs and resources for reimbursements, but receive shares of the lump sum, once work packages have been completed. The net effect for beneficiaries depends on details of implementation and beneficiaries' strategic behaviour (unintended effects) in the medium term.) The currently available evidence base is insufficient to assess the magnitude of the benefit to beneficiaries.		for the project, to justify the lump sums. The cost of generating the budget information is not fully additional but to a large extent part of the baseline: Project management best practice and existing requirements of the programme mean that applicants are assumed to calculate the project budget at proposal stage already. However, adapting the budget to the format, structure and level of detail requested in the proposal template and filling in the template gives rise to additional costs. Any change will be affected by details of implementation, including the availability and user friendliness of guidance for applicants. The currently available evidence base is qualitative and does not allow a quantification of the expected effect on applicants.

ANNEX V. STAKEHOLDER CONSULTATION – SYNOPSIS REPORT

Results of a public stakeholder consultation on the Euratom Research and Training Programme 2014-2020

1. Background and rationale for targeted consultation

In order provide an input for the ex-post evaluation of the Euratom Research and Training Programme 2014-2020, a public stakeholder consultation was carried out by unit RTD C.4 between December 2022 and April 2023.

For fission research (nuclear safety, radioactive waste management and radiation protection), consultation was carried out on the basis EU Survey questionnaire circulated via email to ca. 3740 email addresses of the persons who were involved in 2014-2020 Euratom 99 projects. For fusion energy research, a questionnaire about scientific achievements and implementation was filled on behalf of EUROfusion consortium (almost 200 members) by the EUROfusion Programme Management Unit.

Use of a targeted consultations in different formats allowed to expand questions on scientific/technical aspects of the Programme. While the Euratom questionnaires covered all required elements of the ex-post evaluation, in our analysis we used also results from the Horizon 2020 public consultation, in particular on implementation, administrative burden and simplification. This was possible because the Euratom Programme 2014-2020 was using exactly the same rules, templates and IT systems as thematic areas of Horizon 2020.

The fission questionnaire has over 70 questions including sub-questions. This consultation takes account of all the key evaluation aspects, including questions on relevance, effectiveness, efficiency, progress and delivery of the programme, implementation, cost-benefit, EU added value and stakeholder's identification. Finally, stakeholders could give their opinion about the coherence with other EU policy and the international dimension of the programme.

2. Results and analysis

2.1. Overview of respondents

The Commission received 102 answers from individuals (73%), stakeholders (25%) and umbrella organisations (2%). Answers submitted on behalf of institution, company or umbrella organisations came from: public research organisations (15), higher education institution (11), business (8), regulatory body (2), technical support organisation (3), waste management operator (3), NPP operator (1), private research organisation (3), decommissioning (2). 84 % of respondents were project participants, and 15% we project coordinators. 8% of respondents confirmed that their organisation is SME.

Responses came mainly from respondents based in Italy (15%), Spain (14%), France (13%), Germany (11%), Belgium (7%), Switzerland (6%), Portugal (5%), Czechia, Lithuania, Romania, Sweden, United Kingdom (each 3%), Finland, Netherlands, Poland, Slovakia, Slovenia (each 2%).

Respondents' involvement in specific fields of nuclear research: 49% of respondents were involved in research on nuclear systems and safety, 31% in radioactive waste management, 28% in education & training, 25% in radiation protection (results do not add up to 100% as respondents could indicate more than one reply).

2.2. Analysis

The following general conclusions can be drawn from the analysis of the results of the consultation:

- Project participants were generally highly satisfied with participating in the Euratom programme.
- Respondents were typically very positive in terms of effectiveness (at the outputs and results level) and impact of projects. 90% of respondents indicated that projects could translate outputs into desired results. Almost all respondents (except 3%) indicated that the projects aligned with the Euratom programme's relevant objectives. The main difficulties encountered during the implementation concerned external delays and budgetary limitations.
- The survey identified no significant issues concerning efficiency. The questions on efficiency aimed to gather respondents' perceptions concerning the relationship between the financial and administrative resources used to implement the projects and the project's achievements. Respondents were positive concerning the level of administrative burden for project management and their projects' overall value for money.
- Impact is usually a long-term result and may not be achievable during the project's life cycle. Moreover, the ultimate impact is often influenced by several other factors external to the project, which may either contribute to or detract from the impact of a specific project. Within the context of the Euratom-funded fission research, the impact may include outcomes such as major advances in the current 'state of the art', development of new methodologies or techniques, improved safety, new public policies or the creation of economic value, amongst many others. The survey found that most respondents (88%) considered that the project achieved the expected impacts. The respondents also identified the main types of 'high-level' impacts reached by the projects. According to the respondents, the main impact is creating significant new knowledge in the field concerned by research projects (43% of the answers). It is one of the most expected and foreseeable impacts of research projects. The generation and dissemination of comprehensive new knowledge leading to a redefinition of the accepted 'State of the Art' in the field (31%) were also considered as important impacts by the respondents. The significant reduction in uncertainties or refinement of existing models/techniques is the third category of impacts indicated by respondents (12%). However, 12% of the respondents noted that the question did not apply to their project, mainly because it concerned cross-cutting actions and training projects. The survey also looked at several specific impacts in particular, such as the development of new methodologies, techniques, instruments, demonstrators or prototypes, the filing of new patents, the creation of jobs, new partnerships or new companies, the development of public policy, the improvement of partner competitiveness and the development of spin-off and technology transfers.
- The survey aimed to understand the added value provided by European research projects compared to research conducted on the national or bilateral levels. The respondents were given the opportunity to provide their opinion on several aspects of added value. The main types of European added value underlined by the respondents are the improvement of sharing of knowledge and best practices across borders, the wider dissemination of results allowed by international dimension, the greater cross-border collaboration and mobility, and the contribution to the structuration of research in the area of the project. However, the Euratom

Programme is not considered to have a strong influence on the financial aspects of the projects: only 35% of the respondents agree that the European project allows important economies of scale and 34% that Euratom funding allows their organisation to secure additional national funding.

3. Answers to the consultation

In the following overview of the results, unless specifically indicated, we grouped together different 'yes' and 'no' replies. Replies 'doesn't know'/'no reply' are not indicated unless relevant.

3.1. Effectiveness

Question 1: Considering all factors, how satisfied were you with your participation in the project?

56% satisfied, and **40%** very satisfied, **1%** dissatisfied or very dissatisfied

Question 2: Overall, were the project's expected outputs actually produced?

67% most, **22%** all, **5%** a few.

Question 3: If applicable, what types of difficulties were encountered during the implementation of the project that had an impact on the level of effectiveness? (more than one answer possible)

57% External delays (e.g. extraordinary events, delays in signature of contract, etc.),

36% Budgetary limitations,

20% Internal events,

11% Other,

7% No feasibility of the project

Question 4: Beyond the immediate deliverables of the project, would you say that the project was able to translate outputs into the desired results?

90% To large extent and very much so.

8% Not really and not at all.

Question 5. Overall, do you feel that the project, as implemented, was in line with the relevant objectives of the Euratom programme in your domain?

58% Yes, to large extent, **38%** Yes, very much so, **3%** No,

Question 6. To what extent do you believe that the project contributed to the following results:

Nuclear safety (Reactor systems)

- Creating new knowledge to contribute to the continued safe operation of existing reactor systems (e.g. plant life assessment, safety culture, numerical simulation tools, instrumentation, etc.)

50% Yes, **25%** No,

- Addressing new challenges (e.g. lifetime extension and development of new advanced safety assessment methodologies)
  49% Yes, **26%** No,

- Contributing specifically to the development and/ or maintenance of a high level of safety
  63% Yes, **21%** No,

- Assessing the safety and waste management aspects of future reactor systems (e.g. Gen IV, small modular reactors, etc.)

37% Yes, **37%** No,

- Addressing technologies linked to the performance of future reactor systems (e.g. Gen IV, small modular reactors, etc.)

Yes 42%, **31%** No,

<u>Radiation protection</u>

- Contribute to a better understanding of the risk to health for low and/or protracted exposures
  32% Yes, **34%** No,

- Support the development and/or implementation of sound radiation protection policy

31% Yes, **34%** No

- Enhance the safety and/or efficacy of medical uses of radiation in diagnosis and therapy

26 % Yes, **38%** No,

- Support emergency preparedness for large-scale nuclear accidents or of acts of nuclear terrorism

17% Yes, **47%** No,

- Support remediation of largescale nuclear accidents or of acts of nuclear terrorism
  15% Yes, **47%** No,

<u>Radioactive Waste Management</u>

- Development of new concepts concerning deep geological disposal of spent fuel and long lived radioactive waste (e.g. demonstration of repository design and concepts)
  23% Yes, **39%** No,

- Development / demonstration of technologies for geological disposal (e.g. testing and improving equipment, technologies, etc.)
  17% Yes, **42%** No,
- Development / demonstration of safety for geological disposal (e.g. safety analyses)
  21% Yes, **40%** No,
- Development of a common European view on the main issues related to the management and disposal of waste
  29% Yes, **34%** No,
- Explore potential of concepts that produce less waste during electricity generation (e.g. more efficient use of fissile material in existing reactors)
  17% Yes, **44%** No,
- Research on concepts aimed at reducing the amount and/or hazard of the waste (e.g. partitioning and transmutation)
  20% Yes, **44%** No,

Question 7. To what extent do you believe that the project contributed to the following cross-cutting objectives in the domain of research infrastructure?

- Support the cross-border access to key research infrastructure

50% Yes, **32%** No,

- Support networking in experimental use of infrastructure

57% Yes, **26%** No

- Develop the cooperation between key research infrastructure

73% Yes, **15%** No

- Support the design, refurbishment, construction and/or operation of key research infrastructure

41% No, 36% Yes

Question 8. To what extent do you believe that the project contributed to the following cross-cutting objectives in the domain of mobility and training?

- Contribute to making the sector more attractive to young professionals

74% Yes, **14%** No,

- Contribute to ensuring a training of the next generation of nuclear professionals

75% Yes, **13%** No,

- Contribute to ensuring the career long training needs of engineers and experts

65% Yes, **17%** No,

- Contribute to raising the level of mobility amongst nuclear professionals

45% Yes, **33%** No,

- Did the participation in the project lead to the establishing of durable links and/or cooperation with partners in third countries?

63% Yes, **48%** No,

Question 9. What is the estimated percentage of the total project budget dedicated to training-related activities?

35% Greater than 5%,

44% Less than 5%,

10% Less than 2%,

6% No support for E&T,

3.2. Efficiency

Question 10. Overall, how would you rate the efficiency of your financial and administrative correspondence with the European Commission in your capacity as Project Coordinator?

- Preparation and submission of the project application

61% Efficient and very efficient, **4%** inefficient and very inefficient

- Preparation and signature of the grant

62% Efficient and very efficient, 4% inefficient and very inefficient

- Ensuring the requisite reporting

60% Efficient and very efficient, **8%** inefficient and very inefficient

- Submission of payment claims and receipt of payment

63% Efficient and very efficient, **5%** inefficient and very inefficient

Question 10. Overall, how would you rate the efficiency of the following aspects of the management of the project as a project participant?

- Communication between partners
  90% Efficient and very efficient,
  6% inefficient and very inefficient

- Ensuring the requisite reporting
  89% Efficient and very efficient,
  7% inefficient and very inefficient

- Contacting with project coordinator
  85% Efficient and very efficient,

3% inefficient and very inefficient

- Submission of payment claims and receipt of payment
  81% Efficient and very efficient,
  7% inefficient and very inefficient

Question 11. Overall, would you say that the outputs and results achieved by the project are reasonable given the resources used?

55% Yes, the project delivered at a reasonable cost

38% Yes, the project was an excellent value for money

4% No, the same results could have been achieved for less

3.3. Impacts

Question 12. Overall, to what extent do you believe that the project achieved the expected impacts (e.g. the overall objectives)?

88% Yes, to large extent or very much so,

7% No (not really or not at all)

Question 13. How would you best describe the impacts of the research carried out in the project? If your project does not involve RTD activities, i.e. is a coordination or support action, then you should select 'not applicable'.

43% Significant new knowledge in the field has been created,

31% Comprehensive new knowledge generated and disseminated leading to a redefinition of the accepted 'State of the Art' in the field

12% Significant reduction in uncertainties or refinement of existing models / techniques

12% Not Applicable

Question 14. In your opinion, is the project contributing significantly to the development of new instruments / methodologies / techniques / prototypes / demonstrators?

75% New methodologies,

48% New techniques,

19% New prototypes,

17% New demonstrators,

15% New instruments,

10% Not applicable,

3% Other

Question 15. Has the project resulted in the filling of new patents?

10% Yes,

85% No,

Question 16. Has the project resulted in the creation of new research partnerships?

72% Yes,

24% No,

Question 17. Has the project made an impact on national or European policy in this field?

44% Yes,

49% No,

Question 18. In terms of the economic impact, has the project resulted in the creation of new jobs or companies or otherwise improved the competitiveness of your organisation or one or more partners?

63% Partners have improved their competitiveness as a result of the project

19% New jobs have been created as a result of the project

4% New companies have been created as a result of the project

18% Other

Question 19. To your knowledge did the project result (or is it susceptible to result) in any technology transfers or spin-offs?

49% No

42% Yes, likely in the future

5% Yes, technology transfers / spin-offs occurred

Question 20. Who were the principal end-users of the results of the project? (Respondents could indicate more than one reply)

57% Nuclear industry,

49% University and training authorities,

26% Nuclear safety, health and safety authorities,

26% Radioactive Waste Management Authorities,

25% Technical Safety Organisations (TSOs),

25% Radiation Protection Authorities,

15% Health industry,

9% Others,

Question 21. Have there been any positive impacts on the way your organisation carries out research as a result of involvement in Euratom projects?

- Increased networking within the European R&D sector

73% Yes,

21% No,

- Access to competences not available in your organisation

66% Yes,

24% No,

- Access to additional funding

52% Yes,

44% No,

- Access to key research infrastructures

42% Yes,

46% No,

- Longer term planning as a result of better coordination of research at European level

53% Yes,

31% No,

3.4. Coherence and EU added value

Question 22. To what extent would you say that the project was aligned with national research priorities in your country of residence?

48% Yes, in line with national priorities,

18% Yes, very much aligned with national priorities,

18% No, not really in line with national priorities

3% No, completely unaligned with national priorities

11% I don't know

Question 23. Beyond the objectives of this particular project, would you say that the Euratom Programme is relevant to national research priorities in your country?

39% Yes, in line with national priorities,

27% Yes, very much aligned with national priorities,

17% No, not really in line with national priorities

3% No, completely unaligned with national priorities

12% I don’t know

Question 24. To what extent would you agree with the following statements concerning the different types of EU Added Value created by the project

- The project enabled the sharing of knowledge and best practices across borders

  92% Yes,

  2% No,

- Euratom funding allowed my organisation to secure additional national funding

  55% No,

  34% Yes,

- Euratom support had a structuring impact on research in the area of the project

  77% Yes,

  15% No,

- The project allowed for greater cross-border collaboration and mobility

  83% Yes,

  12% No,

- The international dimension unlocked important economies of scale

  35% Yes,
  36% No,

- The international dimension allowed for a wider dissemination of the results

  90% Yes,

  5% No,