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COMMISSION STAFF WORKING DOCUMENT

EVALUATION

Interim evaluation of the 2021-2025 Euratom research and training programme

Accompanying the document

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

Interim evaluation of the 2021-2025 Euratom research and training programme

{COM(2025) 61 final} - {SWD(2025) 55 final}

Table of contents

GLOSSARY

Term or acronym	Meaning or definition
AMR	Advanced Modular Reactor
CBRN	Chemical, biological, radiological and nuclear materials and agents that could potentially harm the society through their accidental or deliberate release, dissemination, or impacts.
DONES	DEMO-oriented neutron source
DG RTD	European Commission's Directorate-General for Research and Innovation
Divertor	Part of a tokamak where the power exhaust takes place
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
HALEU	High-Assay Low-Enriched Uranium
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
IAEA	International Atomic Energy Agency
IRRS	Integrated Regulatory Review Service missions carried out by IAEA
ITER	International Thermonuclear Experimental Reactor, fusion energy research facility under construction in Cadarache, France (https://www.iter.org/)
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
LWR	Light Water Reactor
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
RWM	Radioactive Waste Management
SME	Small or medium-sized enterprise
SMR	Small and Medium Reactor
SRA	Strategic research agenda
STC	Scientific and Technical Committee 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 purpose 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
TSO	Technical Support Organisation
TRL	Technology Readiness Level
VVER	The water-water energetic reactor is a series of pressurized water reactor designs originally developed in the Soviet Union, and now Russia,

1. INTRODUCTION

1.1. Purpose and scope of the evaluation

This Staff Working Document provides support and evidence for the Commission's report on the interim evaluation of the Euratom Research and Training Programme 2021-2025 (the 'Programme') as required by the Council Regulation establishing this Programme[1]. The Programme is the EU's main funding programme for nuclear research with a budget of nearly EUR 1.4 billion. The Programme funds the development of fusion energy, a long-term option for largescale, low- carbon- electricity production, which could contribute to the EU energy mix in the future. In parallel, the Programme aims at maintaining the highest nuclear safety, security, safeguards and radiation protection standards, as well as Europe's skills in the nuclear domain through the funding of nuclear fission as well as non-power applications of nuclear science and technology research.

The interim evaluation analyses the Programme's design, implementation and first results. The outcome of this evaluation has been used in the preparation and design of the Commission proposal for the extension of the Programme for 2026-2027. The evaluation assesses progress in achieving the Programme's objectives, its efficiency in use of resources, its continued relevance, the coherence within the Programme and with other instruments and its EU added value. It covers the period 2021-2024 and provides a joint assessment of indirect actions implemented by DG Research & Innovation (DG RTD) and of direct actions carried out by the Joint Research Centre (JRC).

For the direct actions, the evaluation was conducted by the Commission services with the support of an external panel of nine independent experts who provided an assessment[2] of the JRC's performance and contribution to the Programme's objectives.

For the indirect actions (research grants and prizes), the evaluation was carried out with assistance of eight independent experts who provided an assessment of the Programme's thematic areas (nuclear safety, radiation protection, radioactive waste management and fusion energy)[3]. The feedback from a call for evidence and public consultation carried out in the context of this evaluation has also been used to assess both direct and indirect actions[4].

The main limitation of this evaluation is that, at this point, the picture of the Programme's implementation and results can only be partial. Evaluation is taking place during the fourth

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1 Art. 14(2) of Council Regulation (Euratom) 2021/765 of 10 May 2021 establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025 complementing Horizon Europe – the Framework Programme for Research and Innovation and repealing Regulation (Euratom) 2018/1563 (OJ L 167I, 12/05/2021, p. 81).

2 Heuer, R., Florea, A.M., Herranz Soler, M., Janowski, T., Keskitalo, E.C.H., Maas, R., Oddou, J., Pálinkás, J. and Wegener, H., Interim evaluation of the activities of the Joint Research Centre under Horizon Europe and Euratom 2021-2025 - Final report of the evaluation panel, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/63710, JRC134811.

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

4 An analysis of the public consultation is provided in Annex V.

year of the Programme's implementation when only one of the 58 projects launched between 2021 and 2024 had been closed. In financial terms, as of December 2024, the cumulative implementation rates are 79% for commitments and 40% for payments.

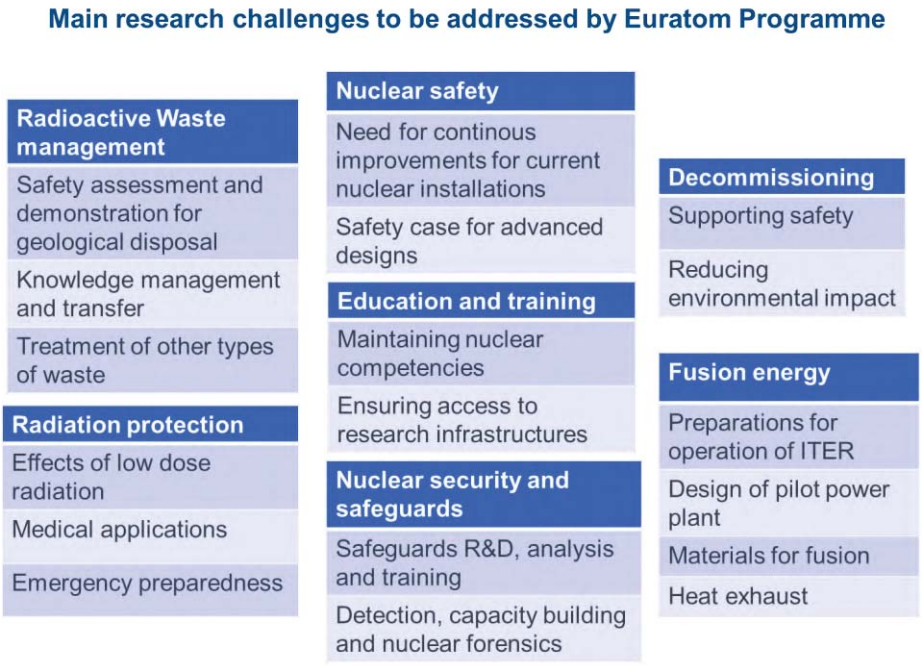
Data limitations include issues related to data availability and measurability of outcomes (e.g. most Euratom Key Performance Indicators (KPI) focus on outputs from research projects such as publications and deliverables), aggregation (e.g. difficulty in aggregating data covering the Programme's whole spectrum coming from various data sources) and reliability of certain data (e.g. data on publications are based on self-reporting by project coordinators). Only partial data is available to the evaluation on the financial support to third parties ("cascading grants"). These grants are not managed through standard Commission IT tools: basic information about participants is submitted in periodic reports by the "first level" beneficiaries arranging the calls but only with a significant delay. For the Euratom co-funded European Partnerships (accounting for 70% of indirect actions), integration in Commission monitoring systems takes place with a considerable time delay.

This limited and, possibly, distorted some of the analysis, especially on the distribution of the funding. 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 thematic coverage and depth. To overcome and mitigate these limitations, this SWD is transparent in indicating its data sources and all underlying sources are available.

2. WHAT WAS THE EXPECTED OUTCOME OF THE INTERVENTION?

2.1. Description of the intervention and its objectives

The Programme deals with power and non-power applications of nuclear technology in the EU and aims to address challenges and issues in the nuclear field (see diagram below) by means of a community-based research programme, complementary to Member States' efforts in these areas[5]. Detailed analysis of research challenges is provided in impact assessment for Commission proposal for 2021-2025 Programme[6].

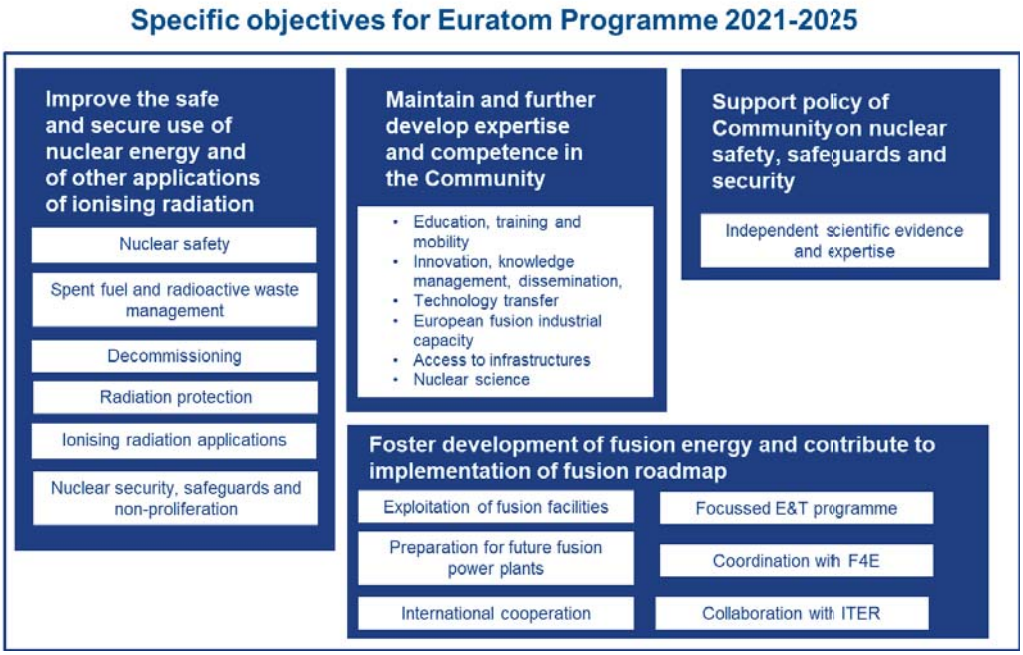


Source: European Commission

The general objective of the Programme (Article 3 of the Council Regulation) is to pursue nuclear research and training activities, with an emphasis on the continuous improvement of nuclear safety, security and radiation protection, as well as to complement the achievement of Horizon Europe's objectives, inter alia in the context of the energy transition. This objective is implemented by four specific objectives using direct and indirect actions (see diagram on next page).

5 Article 4 of the Euratom Treaty

6 See section 2.1.2 of SWD(2018)307, Part 3, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018SC0307



Source: European Commission

Figure 1 on next page shows the Programme's intervention logic. The main elements of each specific objective as implemented during 2021-2025 are explained below.

Specific objective (Article 3(2)a) of the Council Regulation): improve and support nuclear safety, security, safeguards, radiation protection, safe spent fuel and radioactive waste management and decommissioning, including the safe and secure use of nuclear power and of non-power applications of ionizing radiation;

Nuclear safety[7] [8]

The Programme focuses on the safety of operating nuclear power plants, research reactors and other nuclear installations and, where appropriate, of advanced nuclear concepts, fuels and materials, in line with the requirements of the Nuclear Safety Directive[9] and IAEA[10] safety standards. Nuclear Safety Directive introduced EU-wide safety objectives to prevent accidents and radiological releases.

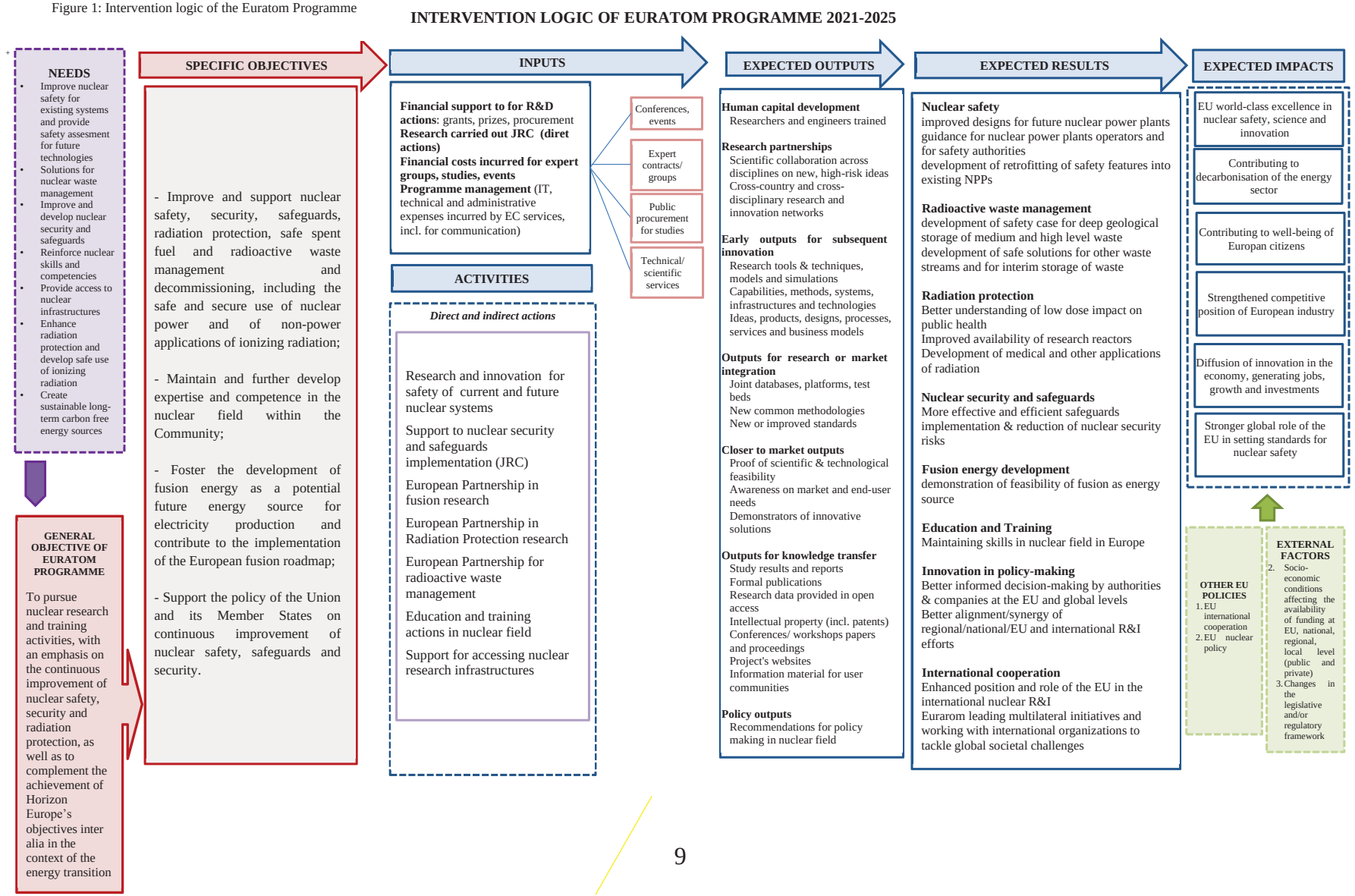
7 More details about research directions in this area are provided in the section (1) 'Nuclear safety' in chapter on strategic orientations for indirect actions in Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

8 See point (a) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme (SWD(2018)307 Part 3, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018SC0307

9 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), as amended by Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations (OJ L 219, 25.7.2014, p. 42).

10 See https://www.iaea.org/resources/safety-standards

Figure 1: Intervention logic of the Euratom Programme



Source: European Commission

For nuclear power plants in operation this implies significant safety improvements and for future nuclear installations, those safety enhancements have to be planned for. Nuclear research priorities are defined around the need to enhance safety assessment methods, to implement a multi-physics multi-scale safety approach, to focus on ageing of materials for a long-term operation perspective, as well as defence in depth requirements, emergency preparedness and modelling under severe accident conditions. 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.

Nuclear security, safeguards and non-proliferation[11] [12]

In the face of geopolitical changes, attention to non-proliferation and security issues is essential, as well as the support provided to EU Member States' authorities. This includes research and training to support law enforcement, civil protection and customs officers in dealing with CBRN threats and developing and improving analytical techniques and methodologies for safeguarding nuclear materials. Innovative concepts are continuously needed as threats evolve and development of nuclear security technologies, in particular related to detection and nuclear forensics, serve to strengthen defence against illicit trafficking. Direct actions implemented by the JRC are developing techniques and methods aimed at reducing nuclear security risks and supporting nuclear non-proliferation efforts. In addition, the JRC works in developing nuclear standards and supporting the implementation of Euratom policies in these areas.

Nuclear science and ionizing radiation applications, radiation protection, emergency preparedness[13] [14]

Outside the power sector, the Programme addresses societal concerns regarding radiation protection. Research plays a key role, providing for better understanding of harmful effects of radiation from natural and artificial sources, and expanding beneficial applications of radiation technologies. The growing number of different applications of ionising radiation requires protecting people and the environment from unnecessary exposure to radiation. Ionising radiation technologies are used daily in fields such as health, industry and research, providing significant benefits to European citizens and the economy. Radiation technologies in particular are increasingly used in the health sector including for diagnosis and treatment, leading to a direct impact on the level of exposure.

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11 See https://joint-research-centre.ec.europa.eu/scientific-activities-z/nuclear-safeguards_en

12 See point (e) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme

13 More details about research directions in this area are provided in the section (3) 'Nuclear science…' in chapter on strategic orientations for indirect actions in Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

14 See section point (b) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme

With clinical applications of imaging techniques using ionising radiation cover a large spectrum, therapeutic clinical applications using radioisotopes are expected to grow, contributing prominently to the fight against cancer. The main uncertainties in radiation health risk evaluation are in the magnitude of cancer risk at low and protracted doses, the magnitude of non-cancer effects and the variation in disease risk between individuals in the same population. Therefore, the key research questions are the dose and dose-rate relationship for cancer, non-cancer health effects and individual radiation sensitivity.

Research at low dose rates or low doses presents significant challenges in the investigation of both radiation-related health effects and underlying biological mechanisms because the magnitude of health risk and biological effects is expected to be low. A multidisciplinary approach is therefore essential 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 innovative 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 helps Member States and stakeholders in implementing the Basic Safety Standards Directive[15].

Safety concerns over potential nuclear and radiological incidents, especially in the wake of the Russian war of aggression in Ukraine and associated security threats, have heightened the need for strengthening emergency preparedness in the EU. This is grounded in the **continuous environmental radiation monitoring (REM)** guaranteed by both the European Radiological Data Exchange Platform (EURDEP) and the European Community Urgent Radiological Information Exchange (ECURIE) system. The JRC provides technical support to keep these systems active and continuously improve their efficiency and operability. Specialised tools and methods used to forecast and model radioactivity releases, including transport and dispersion models, also provide additional support to emergency preparedness in the EU.

Radioactive waste management and decommissioning[16] [17]

An integrated and robust radioactive waste management system is a prerequisite to all nuclear activities. All Member States generate radioactive waste through activities ranging from non-power applications to electricity generation and to research. In 2019 this stood

[15] 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).

[16] More details about research directions in this area are provided in section (2)'Spent fuel and radioactive waste management' in chapter on strategic orientations for indirect actions in the Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

[17] See point c) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme

at 55 600 tonnes of heave metals of spent fuel from both power and non-power reactors[18]. Owing to the potential radiological hazards it poses to workers, the general public and the environment, radioactive waste and spent fuel must be safely managed through characterisation, minimisation of the amount of radioactive waste generated and containment and isolation from humans and the living environment. The main challenge today remains the implementation of disposal options for spent fuel and high-level radioactive waste over exceptionally long timescales. In line with the Council regulation establishing the Programme[19], research should focus on optimising safety margins and minimising practical uncertainties around disposal technologies, while ensuring reliable knowledge management and transfer to next generations in the case of geological disposals. The issue of storing and disposing of other types of waste such as legacy waste or waste originating from experimental and fuel cycle developments also needs to be addressed by research.

Over the past five decades, the concept of a deep geological repository (DGR) for high-level radioactive waste has evolved from an abstract idea into a tangible reality. In the EU, repositories in Finland, Sweden and France are at various stages of licensing for their respective concepts, while the remaining Member States continue to explore diverse options.

Ongoing research, development, and demonstration are crucial for evaluating alternatives such as deep boreholes, diverse host rocks, innovative construction technologies for DGRs, and advanced materials for predisposal operations. Additionally, novel approaches for monitoring waste packages and the behaviour of engineered barrier systems remain necessary.

Council Directive 2011/70[20] Euratom establishes a Community framework for the responsible and safe management of spent fuel and radioactive waste and requires Member States to set up appropriate national arrangements for the safe management of spent fuel and radioactive waste, to protect workers and the general public against the dangers arising from ionising radiation. The EURAD Partnerships, initiated in 2019, aim to address this challenge by creating a network and platform for implementors, regulators and research entities involved in radioactive waste management across all Member States. The focus of these partnerships will gradually shift toward knowledge management and transfer among stakeholders, countries and generations.

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18 Commission Staff Working Document Inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects Accompanying the document Report From The Commission To The Council And The European Parliament on progress of implementation of Council Directive 2011/70/EURATOM and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects - Third Report (SWD(2024)127, 22.05.2024).

19 See point (a)(ii) of Annex I to Council Regulation (Euratom) 2021/765 of 10 May 2021

20 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.

A growing number of the EU's operating nuclear reactors is reaching their end of their lifecycle and need to be shut down[21]. Development of innovative decommissioning techniques and reduction of environmental impact is crucial, timely and needed.

Specific objective (Article 3(2)b): maintain and further develop expertise and competence in the nuclear field within the Community[22] [23]

Under this specific objective, Council regulation foresees a broad spectrum actions in education, training and mobility, promotion of innovation, knowledge management, dissemination and exploitation, as well as access to infrastructures. EU Member States are faced with concerns over an ageing workforce and difficulties in recruiting the next generation of qualified staff required for the nuclear sector, with a perceived risk of loss of competences at EU level. A wide array of skills is required to underpin the continuous safe operation of nuclear and related installations, which encompasses all power and non-power areas of nuclear science, from safety to radiation protection, safeguards, nuclear waste management and ionising radiation applications. Nuclear knowledge management and transfer, as well as the provision of education and training are essential prerequisites to preserve the highest safety and security standards in the nuclear field in the EU and to maintain technological leadership, especially for research into advanced nuclear applications. Maintaining European nuclear infrastructures and making them available and accessible is critical to ensuring research and development in most areas of the nuclear field. There are also essential tools for knowledge sharing, capacity building and researcher mobility.

Specific objective (Article 3(2)c): foster the development of fusion energy as a potential future energy source for electricity production and contribute to the implementation of the European fusion roadmap[24] [25]

The Programme focuses on developing fusion energy as a possible option for low carbon electricity production, which could help address climate change and the growing demand of energy in the long term. Fusion would be a continuous source that comes without major safety risks or waste and proliferation issues. To prepare Europe for fusion deployment, the research and technological development must first demonstrate the scientific and

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21 74 Nuclear Power Plants are permanently closed down in 10 Member States, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Nuclear_energy_statistics

22 More details about research directions in this area are provided in section (4)'Maintaining…' in chapter on strategic orientations for indirect actions in the Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

23 See point (f) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme

24 More details about research directions in this area are provided in section (5)'Development of fusion energy' in chapter on strategic orientations for indirect actions in the Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

25 See point (g) of section 2.1.2 of impact assessment for Commission proposal for 2021-2025 Programme

technical feasibility of fusion energy before going into its commercial and economic viability.

While these scientific and technological challenges are immense, considerable progress has been made in understanding the behaviour of self-sustaining plasmas[26], although more data is needed to perfect our models. Developing materials that can endure the intense heat and neutron exposure in a fusion reactor is another hurdle, as no current facility can test these materials under the exact conditions they would face. Additionally, turning fusion into a practical electricity source involves solving complex engineering problems, such as designing components that can handle extreme temperatures and are also maintainable. There are also challenges related to tritium fuel use, including supply, safety, and security concerns. The Programme aims at demonstrating the feasibility of fusion as an energy source by exploiting research facilities and developing necessary materials, technologies and conceptual design[27].

Specific objective (Article 3(2)d): support the policy of the Union and its Member States on continuous improvement of nuclear safety, safeguards and security.

The JRC is tasked[28] to provide independent, scientific and technological support for formulating, developing, implementing, and monitoring the nuclear Directives and Regulations (Nuclear Safety[29], Basic Safety Standards[30], Spent fuel and Radioactive Waste Directive[31], Shipment Directive[32] and Nuclear Safeguards[33]) and regulatory requirements. JRC also supports the implementation of the European Instrument for International Nuclear Safety Cooperation[34] managed by DG INTPA[35] and provides technical and scientific support to Euratom as party to International Conventions.

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26 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

27 See point (c) of Annex I to Council Regulation (Euratom) 2021/765 of 10 May 2021

28 See point (d) of Annex I to Council Regulation (Euratom) 2021/765 of 10 May 2021

29 Council Directive 2009/71/EURATOM establishing a Community framework for the nuclear safety of nuclear installations

30 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

31 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

32 Council Directive 2006/117/Euratom of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel

33 Commission Regulation (Euratom) No 302/2005 of 8 February 2005 on the application of Euratom safeguards

34 Council Regulation (Euratom) 2021/948 of 27 May 2021 establishing a European Instrument for International Nuclear Safety Cooperation complementing the Neighbourhood, Development and International CooperationInstrument – Global Europe on the basis of the Treaty establishing the European Atomic Energy Community, and repealing Regulation (Euratom) No 237/2014.

35 European Commission's Directorate-General for International Partnerships

Provisions introduced or modified in 2021-2025 Programme

The Programme's overall scope remains unchanged compared to the 2014-2020 Programme, with a focus on nuclear safety and security, radiation protection, radioactive waste management and fusion energy. However, to address issues raised by the interim evaluation of 2014-2018 Programme[36], the Programme introduced a number of modifications[37]. The modifications concern mainly the structure of specific objectives, their content (defined in Annex I to the Regulation) and introduction of provisions on synergies with Horizon Europe:

1) **Simplification of specific objectives**: a single set of four specific objectives for direct and indirect actions was introduced in the basic act replacing 13 separate specific objectives in 2014-2020 (8 for indirect and 5 for direct actions). The aim was to simplify implementation and have direct and indirect actions address the same objectives. It should also enable synergies between direct and indirect actions of the Programme and facilitate research consortia's access to the JRC's infrastructure and knowledge base.
2) **Introduction of provisions on cross-cutting actions with Horizon Europe Framework Programme**: both basic acts provide for synergies (For Euratom in the Article 10, for HE in Annex IV) with focus on education and training actions (MSCA in particular) and on joint research for cross-cutting aspects of the safe and secure use of non-power applications of ionising radiation in sectors such as medicine, industry, agriculture, space, climate change, security and emergency preparedness and contribution of nuclear science.
3) **Expansion of the scope of research in radiation protection:** in addition to medical applications of ionising radiation, the Programme now also covers applications in industrial and other research fields;
4) **More precise definition of the research support for decommissioning**: the 2014-2020 Programme contained only a short reference to decommissioning in the specific objective for safety. The new Programme provides definition for actions in this field including the development and evaluation of technologies for decommissioning and environmental remediation of nuclear facilities and sharing of best practices and knowledge on decommissioning. The focus on decommissioning reflects the early decommissioning demand based on the public interest, the principle of environmental remediation, and the current and future high number of permanently shut down nuclear reactors.
5) The Euratom Programme complements the Horizon Europe Framework Programme, sharing with it the horizontal provisions, instruments and rules for participation. As a result, **simplification measures[38] introduced by the HE regulation are also applicable to the Euratom Programme 2021-2025.**

[36] See Commission report COM(2017) 697, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017DC0697

[37] See section 2.2.2. of impact assessment for Commission proposal for 2021-2025 Programme (SWD(2018)307 Part 3, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018SC0307

[38] Such as single cost option and administrative simplification. For more details see section 4.2.3.

2.2. Points of comparison

Where the expected effects were quantitatively estimated or targets were set in the Euratom Programme impact assessment or in the legal base, this evaluation compares the actual Programme's data to these expectations. This is the case for the analysis of some key performance (KIP) indicators and efficiency metrics (time to grant, etc.).

In the absence of targets, this evaluation compares the current Programme's performance with data from the implementation of the previous Euratom Programme. This is the case for thematic coverage, participation statistics, JRC contributions to policies. If none of the above is possible, newly available data on the Programme's implementation is presented, without any baseline nor benchmark.

3. HOW HAS THE SITUATION EVOLVED OVER THE EVALUATION PERIOD?

3.1. Current state of play

The Euratom Research and Training Programme 2021-2025 (the 'Programme') was launched in May 2021 with a total budget of EUR 1.39 billion (see table 1). By end of 2024, 79% of the budget had been committed and 40% of the payments made[39]. The Programme is implemented in direct management through indirect and direct actions, making up 61,5% and 38,5% of the budget, respectively.

Figure 1: Euratom Programme's key figures

Source: European Commission

Between 2021 and 2024, 82 grants for projects, fellowships and awards were signed, with EUR 812 million in Euratom contribution (see table 3). 51 project grants for EUR 238 million (30% of the total) were selected on the basis of the competitive call for proposals, while 7 grants for EUR 572 million Euro (70% of the total) were awarded to named beneficiaries, mainly the co-funded European Partnerships in fusion research and radioactive waste management. While funding for EUROfusion was already agreed to in the Council Regulation, the other beneficiaries were indicated in the work programmes adopted by the Commission with agreement of Member States. All proposals were evaluated to the same standards as in open calls for proposals.

[39] All figures in this chapter come from European Commission, cut-off date is end of 2024.

Table 1 : Budget overview of the Euratom Programme 2021-2025 (commitments)						
	2021	**2022**	**2023**	**2024**	**2025**	**TOTAL**
Fusion research (indirect actions)	101 864 137	106 293 454	110 561 358	113 764 360	118 144 233	550 627 542
Fission research (indirect actions)	46 252 776	48 286 116	60 054 175	51 959 861	53 960 162	260 513 090
Fission research (JRC operational budget)	8 918 098	8 130 000	8 130 000	8 055 381	8 055 382	41 288 861
Indirect actions (administrative budget)	8 729 241	8 891 897	9 307 305	9 474 001	9 696 274	46 098 718
Direct actions (JRC administrative budget)	98 984 259	98 108 880	97 982 000	97 982 000	97 982 000	491 039 139
Total	264 724 945	269 710 347	286 010 992	278 354 990	287 838 051	1 389 567 350

Source: European Commission

The **JRC direct actions**, the budget is distributed across three main categories (see table 2): staff expenses for permanent and non-permanent personnel (making up around 60% of the budget and covering mainly highly specialised researchers); means of execution for maintenance of building and operational expenses for scientific work. Both staff expenses and means of execution represent the administrative budget.

Table 2: Direct actions budget distribution by expenditure categories	
Staff expenses	63,1%
Means of execution	29,1%
Operational expenses	7,8%

Source: European Commission

Following the **3 competitive calls for proposals**[40], 96 proposals were received by the Commission. The overall success rate of proposals was 53%, compared to 37% for the Euratom Programme 2014-2020, with 51 proposals retained for funding. Additional 11 proposals were placed on the reserve list and an additional EUR 35.6 million would have been needed to fund these proposals, covering mainly research in radiation applications & protection (5 proposals) and safety of current systems (4 proposals).

[40] See call topics and budget allocation in the text of Euratom Work Programmes:
Euratom Work Programme 2021-2022 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2021-2022/wp_euratom-2021-2022_en.pdf
Euratom Work Programme 2023-2025 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

Table 3: implementation of indirect actions under Euratom Programme 2021-2025			
Euratom indirect actions	**Grant value**	**Total costs of actions**	**Number of grants**
Calls for proposals			
2021-2022 call for proposals	116 276 166,47	150 617 232,08	29
2023-2025 call for proposals	100 913 059,86	130 132 928,72	20
2022 ad-hoc for proposals for safety of VVER fuel	20 515 092,50	39 634 933,75	2
Euratom contribution to MSCA post doc fellowships	2 184 468,47	2 184 468,47	12
Prizes (SOFT Prize and Nuclear Innovation Prize)	400 000,00	400 000,00	12
Grants to named beneficiaries			
European Partnership in fusion energy research (EUROfusion)	549 442 000,00	1 001 448 247,98	1
European Partnership for radioactive waste management (EURAD-2)	20 000 000,00	34 380 393,16	1
Other grants to named beneficiaries[41]	2 699 820,00	3 890 068,75	5
TOTAL	**812 430 607,30**	**1 359 646 238,16**	**82**

Source: European Commission

Most of the Euratom grants (EUR 619 million, 76% of budget for indirect actions) were awarded to the **cofunded European Partnerships**. The Programme launched four Partnerships: in fusion research (EUR 549 million), radiation protection (EUR 29 million), radioactive waste management (EUR 20 million), nuclear materials (EUR 20 million).

The JRC participates, as a beneficiary requesting no funding, in 27 of the 58 consortia selected and contributes to 2 of the 4 co-funded European Partnerships, namely EURAD-2 on radioactive waste management and CONNECT-NM on nuclear materials.

The Commission also published **three calls for recognition prizes**: the Nuclear Innovation Prize in fission (in 2022) and the SOFT Innovation Prize in fusion (in 2022 and 2024). 47 proposals were received, and 12 prizes were awarded for a total of EUR 0.4 million.

In line with provisions of the Programme (Article 10) and Horizon Europe (Annex IV on synergies), **Euratom funding was provided to Maria Skłodowska-Curie Actions (MSCAs)** to make nuclear researchers eligible for MSCA Postdoctoral Fellowships. Since the 2021, 32 applications from nuclear researchers were submitted, out of which 15 were selected following the same process as for all MSCA grants. Grant agreements have been signed for all selected applications of the 2021-2023 calls[42], to a total Euratom contribution of EUR 2.2 million (i.e. 73% of the EUR 3 million budgeted over the same period).

The **average grant size for collaborative projects**, excluding European Partnerships is EUR 3.9 million, slightly higher than the EUR 3.8 million for the 2014-2020 Programme. Collaborative grants now involve an average of 16 participants, compared to 18 for the

[41] Support for IFMIF-DONES, FISA/EuradWaste conferences, training support for Ukraine

[42] At the time of writing of this report, MSCA grant agreements for the 2024 were still to be signed.

2014-2020 Programme. On the other hand, three co-funded European Partnerships in fission research, involving about 81 participants each, received EUR 23 million of Euratom funding on average. **Average funding rate for collaborative projects is at 79%** (75% for the 2014-2020 Programmes), with the Programme mobilising EUR 52 million from stakeholders. On the other hand, the average funding rate for co-funded European Partnerships is 55%, with the Programme mobilising in total EUR 494 million from stakeholders.

The projects signed in the first four years of the Programme involve around **967 distinct participants from Member States and 15 from Ukraine** (only country associated to the Programme) and 53 from third countries: Canada, China, USA, Japan, South Korea, South Africa, Türkiye, Norway, Switzerland and the UK.

SMEs accounted for 9% of participations and received about EUR 13 million in grants, 5% of the total awarded through calls. To be noted, the Programme does not offer specific support to SMEs.

Member States account for 98% of total funding, while Ukraine accounts for 2%. Support for third countries was extremely low (EUR 560 000), their participation being limited to cases where their participating entities were considered, by independent experts, essential for the implementation of project.

There are **no major differences in participation rates between well-established research centres and entities from so-called widening countries**. Entities from Member States which joined since 2004 were involved in 90% of selected projects for fission research in the 2021-2022 and 2023-2025 call. Participants from these Member States are also taking on the role of project coordinators more often, for 5 out of 30 projects in the 2021-2022 and 2023-2025 call. The Programme's financial contribution to fission research in these Member States went from EUR 9 million in 2014-2020 to EUR 12 million in 2021-2025. There are no strong East-West or North-South divides with countries like Spain and Italy being strong actors in the Programme. Member States not using nuclear power participate mainly in projects concerning radiation protection, medical applications and nuclear waste management. Some, like Austria, Denmark, Greece, Ireland and Portugal, also participate in research for nuclear safety and nuclear data to maintain domestic competences.

The Programme also attracted new participants in projects launched since 2021. About 15% of all participants are newcomers who received 7% of total funding. Half of this funding went to research for radiation applications and protection.

The highest share of participants comes from research organisations (42%), rather than higher education institutions (25%) and private sector entities (23%).

In terms of **grants per research field in nuclear fission** (see table 4), research on safety received 63% of funds, followed by radiation applications and protection (19%),

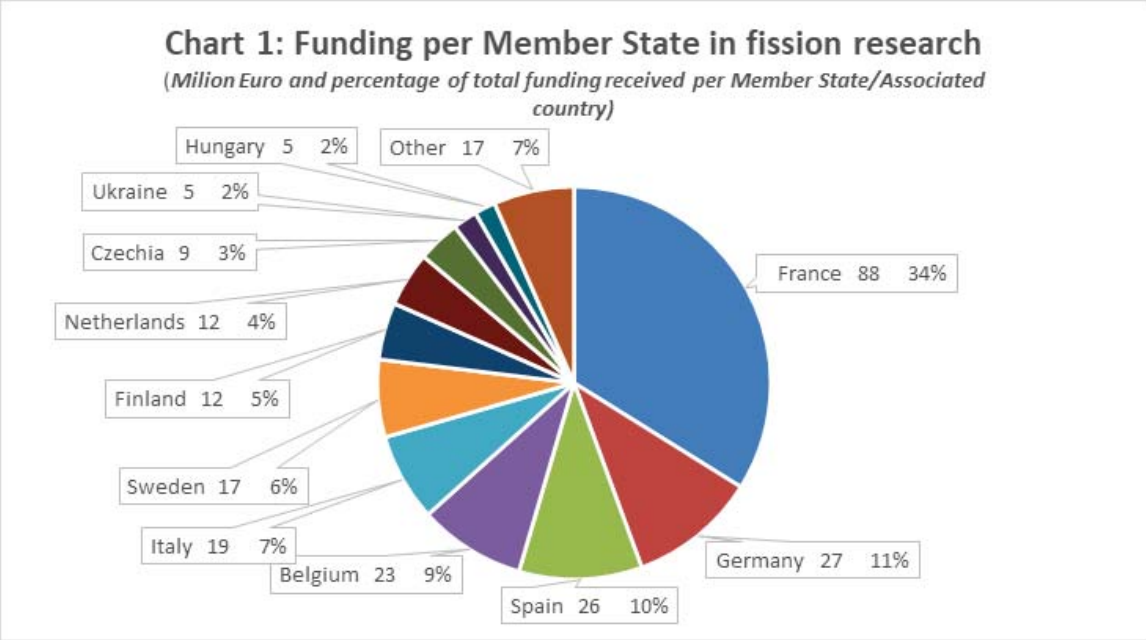
radioactive waste management (9%), actions for expertise and competences in nuclear field (7%), and decommissioning (2%).

Table 4: Euratom funding (indirect actions) in million euro per research field				
Research field	**Euratom grants (million euro)**	**Total costs (million euro)**	**Average funding rate (%)**	**Number of grants**
Nuclear Safety (total)	**164,6**	**228**	**72%**	**34**
Current nuclear systems	50,3	59,2	85%	11
Fuel cycle	45,6	71,4	64%	9
Advanced systems	33,5	42,2	79%	9
Nuclear materials	28	46,4	60%	2
Nuclear Data	4	4,8	83%	1
Nuclear innovation	3,2	4	80%	2
Radiation applications and protection	**50,2**	**67,3**	**75%**	**9**
Radioactive waste management	**22,5**	**34,38**	**58%**	**2**
Decommissioning	**3,9**	**4,2**	**93%**	**2**
Expertise and competences	**18,4**	**19,4**	**95%**	**26**
Education, training, mobility	6,8	7,2	94%	1
Access to infrastructure	9	9,6	94%	1
MSCA post-doc fellowships	2,2	2,2	100%	12
Recognition prizes	0,4	0,4	100%	12
Fusion energy	**550,65**	**1002,9**	**55%**	**2**
EUROfusion	549,4	1001	55%	1
IFMIF Dones	1,25	1,9	66%	1
Other actions[43]	2,7	3,9	70%	7
Total	**812**	**1360**	**60%**	**82**

Source: European Commission

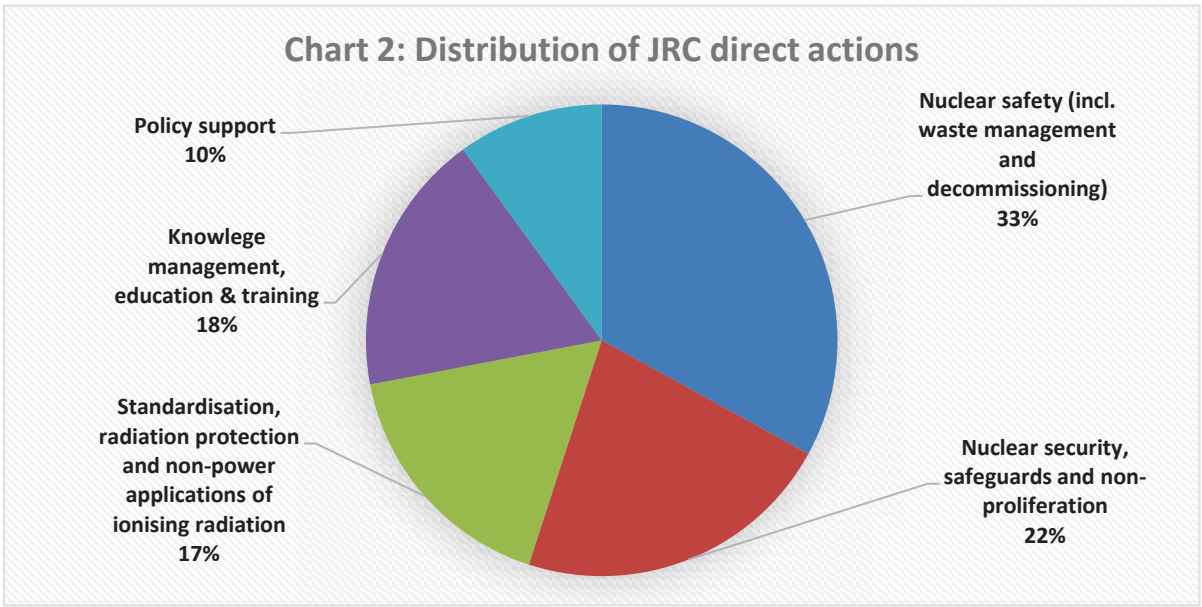
Regarding funds received and participation of Member States and third countries (see Chart 1), during 2021-2025 almost all Member States were involved in the fission research indirect actions with multiple participations in projects. Data shows that Euratom funding is highly concentrated in few Members States – the first three Member States in terms of grants awarded (France, Germany, Spain) received more than half of all Euratom funds (56% compared to 52% in 2014-2018), while organisations in top 10 countries received 93% of funds, compared to 88% of funds in 2014-2018. Note the prominent position of country associated to the Euratom Programme – Ukraine, which received more than EUR 5 million.

[43] Support for Fisa/EuradWaste conferences, National Contact Points, SNETP Forward project.



Source: European Commission

During 2021-2024, the **breakdown of activities for the JRC direct actions** (see chart 2) has resulted in the following distribution across research areas: 33% dedicated to nuclear safety research (including waste management and decommissioning); 22% to research on nuclear security, safeguards and non-proliferation; 17% to research on standardisation, radiation protection (including environmental monitoring) and non-power applications of ionising radiation; 18% to knowledge management, education and training activities; and 10% to directly support EU policies.



Source: European Commission

External factors impacting the JRC performance: the COVID-19 pandemic had a significant adverse impact on the JRC's activities during the first two years of the programme, particularly affecting the access to research infrastructures, both for external parties as well as for JRC researchers, constraining the availability of human resources and incurring additional operational costs. Several other factors have also put a strain on the JRC's activities under the direct actions. Due to the Russian war of aggression in Ukraine and ensuing energy crisis, energy costs (electricity and gas) have increased substantially in all JRC sites in 2022 and in 2023. The resulting inflation has led to higher operational costs for the research sites, associated with security contracts and radiation protection expenses, and higher staff costs in the short run and even more so on the long run owing to the compounding effect of inflation. This upward trend in costs has proved impactful as a relevant share of the JRC budget is characterised by fixed costs (mainly staff and infrastructure). Against a fixed and reduced Euratom financial envelop in the current financing period, this puts even more pressure on the JRC's research activities.

4. EVALUATION FINDINGS (ANALYTICAL PART)

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

The Euratom programme is successful in supporting pertinent research on nuclear safety, security, safeguards, radiation protection, waste management and fusion energy. It is too early to draw conclusions on the programme's impact – because only one project had been completed by 2024 and 10 more will be completed in 2025, out of 58 launched[44]. However, available monitoring data and outcomes in terms of projects launched, their coverage and first results, as well as JRC outputs, show that the programme's direct and indirect actions implemented over the last four years are relevant for achieving its objectives. Reporting shows that projects launched in 2021 and 2022 reached 53% of their milestones. The programme has delivered in terms of peer-reviewed scientific publications (ca. 2000) and the number of people who have benefited from training, mobility and access to research infrastructure (ca. 11 000).

Co-funded European partnerships in nuclear research attracted research institutions from most Member States (21 in radioactive waste management, 23 in radiation protection and 26 in fusion energy). The partnerships also made use of substantial funding from participants as 45% of the costs are covered by beneficiaries. Progress made by partnerships is attracting more partners from non-EU countries; for instance, in radioactive waste management the number of partners doubled to 22.

The data and analyses available at the time of writing shows that progress is being made in achieving the programme's objectives as explained in the sections below.

4.1.1. Effectiveness of the Programme

The key performance indicators (KPIs) established by the Council regulation[45] provide a preliminary picture of the immediate outcomes of direct and indirect actions. The KPIs[46] show that the Programme delivers in terms of peer reviewed publications, deliverables for nuclear safety, security and safeguards, such as databases and information systems, datasets, reference materials, reference methods and measurements, as well as other outputs like technical reports in support of Commission policy making in the nuclear field. Four KPIs have already reached their target. In particular, the Programme already exceeded target for the number of people having benefited from upskilling activities under the Euratom programme through training, mobility and access to infrastructure thanks to several new initiatives in this field. Recent successes in experimental campaigns in fusion research are reflected in the KPI showing progress in implementation of the EUROfusion

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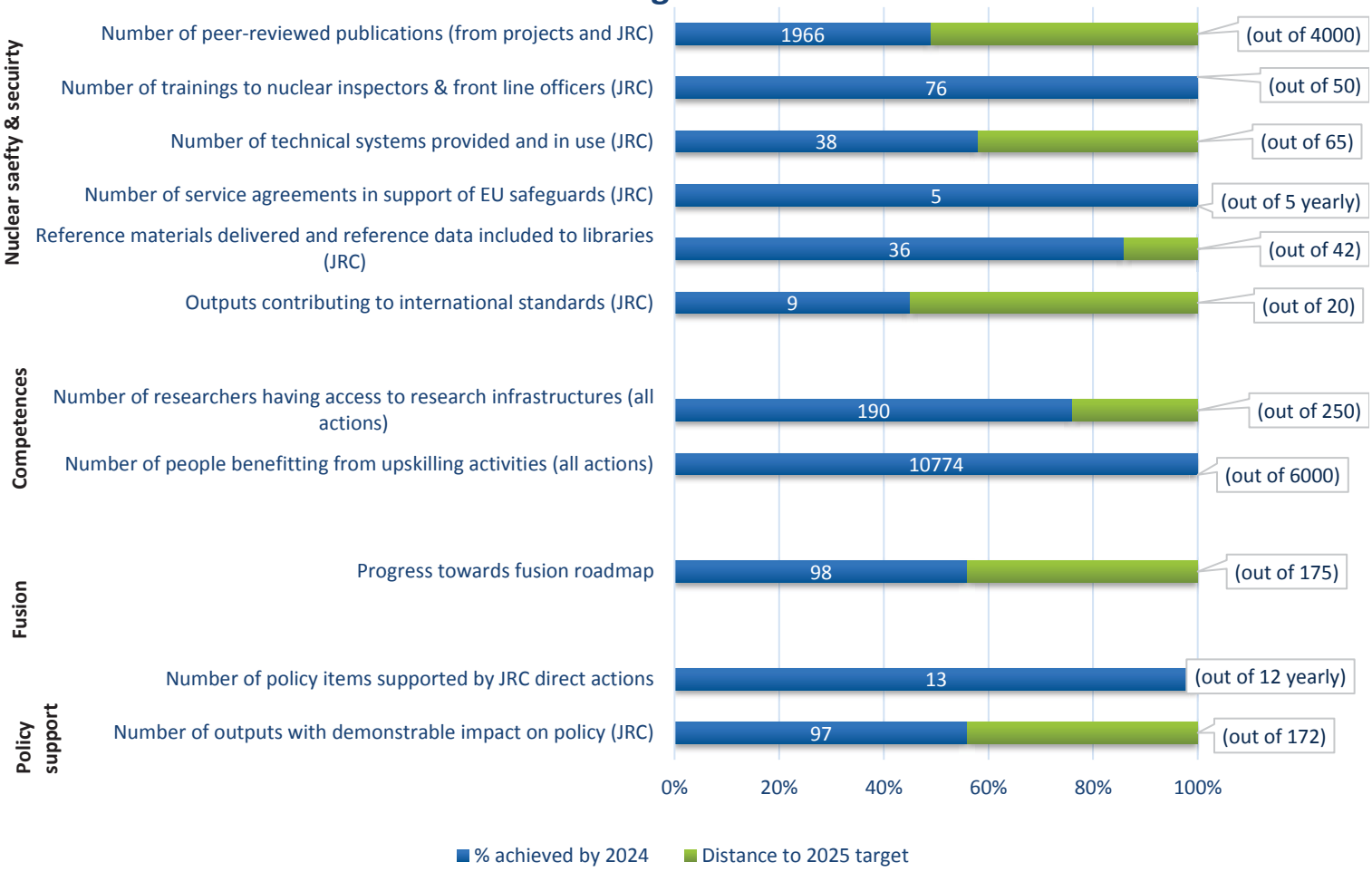
44 List of projects is provided on EU Funding & Tenders Portal - https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-results?isExactMatch=true&frameworkProgramme=43298916&order=DESC&pageNumber=NaN&sortBy=title

45 Annex II to Council Regulation (Euratom) 2021/765 of 10 May 2021

46 For more details https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/programme-performance-statements/euratom-research-and-training-performance_en

roadmap, which reached half mark in term of milestones. Detailed analysis is provided per each specific objective in sections below.

Chart 3: Key Performance Indicators for Euratom Programme 2021-2025



Source: European Commission

4.1.2. Research for nuclear safety

Research highlights

- **The need to maintain high level of safety of the current EU nuclear fleet is well addressed** by a considerable number (7) of projects dealing with Long-Term Operation and related issues**.**
- 5 projects on various aspects of **safety and licencing of light water Small Modular Reactors** (total value of grants: EUR 26.9 million), facilitating SMR development and deployment[47].
- 2 projects funded aiming at improving **safety and security of supply of fuel for VVER nuclear power plants** in Bulgaria, Czech Republic, Finland, Hungary, Slovakia, Ukraine.
- Launch of **co-funded European Partnership** (CONNECT-NM, EUR 20 million) to accelerate **innovation in nuclear materials**.

Large portfolio of projects addressing a broad spectrum of safety issues - during 2021-2024 the Euratom Programme supported long-term and exploratory safety research through collaborative projects and JRC's direct actions. The Commission launched 34 projects with grants for total amount of EUR 164.6 million. JRC participates in 19 projects (see tables 5 to 8) providing access to research infrastructures and expertise. Together with its own actions, JRC devoted 33% of resources to this research field.

Table 5 – Research projects for safety of current nuclear systems (grants in million Euro)

Project	Brief description	JRC	Grant
ASSAS	Development of severe accident simulator with use of AI		3
DELISA-LTO	Tools for assessment of system integrity for long term operation		3,3
EASI-SMR	Safety Innovations for light water SMRs	X	15
EVEREST	Validation of multi-physics models for pressurised water reactors		4,1
FIND	Development of monitoring for structural health of NPP piping		5
GO-VIKING	Advanced modelling for flow-induced vibrations in NPPs		3
Magic-RR	Materials ageing and structural integrity of Research Reactors		3,2
SANE	Safety Assessment of non-electric uses of nuclear energy		3,5
SASPAM-SA	SMR safety analysis with mitigation strategies for severe accidents	X	3
SEAKNOT	Analysis and update of current knowledge on severe accidents		2,2
SOCRATES	Assessment of liquid source term during severe nuclear accidents	X	5
Total			50.3

Source: European Commission

[47] For more information on Euratom projects supporting research for SMRs, see https://research-and-innovation.ec.europa.eu/document/download/74b352e3-cd1e-4b53-a341-7f495b64ec46_en?filename=ec_rtd_smr-projects.pdf

Out of the 34 projects launched, eleven focus on the safety of current systems (operating NPPs and systems close to deployment like Light Water SMRs, see table 5), nine address the safety of advanced nuclear designs (see table 6), nine concerns fuel cycle (see table 7), and five concern nuclear materials, data and new applications of nuclear technologies (Table 8).

Table 6 – Research projects for safety of advanced nuclear systems (grants in million Euro)			
Project	**Brief description**	**JRC**	**Grant**
ANSELMUS	Safety assessment of heavy-liquid-metal systems	X	3,5
ENDURANCE	Research on critical technology elements for molten salt reactors	X	4
ESFR-SIMPLE	Safety design assessment for sodium fast reactor	X	3,4
GEMINI 4.0	Safety demonstration for high temperature reactor	X	2,9
HARMONISE	Scientific basis to facilitate licensing of advanced reactor systems	X	2,5
LESTO	Safety design and tools for lead fast reactor		4
MIMOSA	Multi-recycling of spent fuel using molten salt technology	X	5,8
TANDEM	Assessment and tools for integration of SMRs in hybrid energy systems	X	3,4
TREASURE	Safety demonstration for gas-cooled fast reactor		4
Total			33,5

Source: European Commission

Results of projects' monitoring by the Commission – the first **20 projects** launched in 2022-2023 **achieved on average 47% of milestones.** They involve about **62 PhD students**[48] and produced **54 peer reviewed articles**[49]. Euratom projects cover research for improving safety assessment methods, including ageing of materials for a long-term operation, as well as modelling under severe accident conditions. Based on the agreed scope of work and progress made until end of 2024, the projects should produce knowledge supporting a science-based assessment of the safety margins and benefit periodic safety reviews of existing nuclear installations. To ensure relevance of the research work, many Euratom-supported projects involve utilities and/or regulators through project advisory boards.

Results of independent evaluation - 20 projects were subject to mid-term evaluation by independent experts[50]. **The mid-term evaluation concluded these projects are relevant to the safety of current and advanced nuclear systems, including fuels and fuel cycles**. In particular, some important projects address the long-term operation of existing EU nuclear power plants (NPPs), in particular the need to further support the understanding of degradation and aging of different installations. This will allow determine the most

48 Data from Commission reporting system (SYGMA)
49 Data from Scopus, December 2024
50 Liisa Heikinheimo, Stefano Monti, *Interim evaluation of indirect actions for nuclear safety under Euratom Research and Training Programme 2021-2025 and recommendations for 2026-2027 extension*, June 2024

affected and threatened NPP components and describe the effects of the LTO on the material properties as well as develop simulation tools able to predict their evolution.

The experts' evaluation acknowledges the efforts to address HALEU and other advanced fuels' supply chain issues and the importance of the project for early-stage safety and regulation considerations for the deployment of Small Modular Reactors (SMRs). It also highlights relevance of actions for maintaining knowledge on advanced nuclear systems and extending nuclear energy applications beyond electricity. Notable projects address important issues on tritium management in fission and fusion facilities, and the need for well-characterized innovative materials for novel reactor concepts.

Table 7 – Research projects for nuclear fuel cycle (grants in million Euro)

Project	Brief description	JRC	Grant
APIS	Action to improve security of supply of fuel for VVER NPPs	X	10,5
EU-CONVERSION	Low-enriched uranium fuels for research reactors		7,6
FREDMANS	Nitride fuels development and recycling of spent fuel	X	2,5
OperaHPC	Computer modelling for enhanced accident tolerant fuels	X	3
PreP-HALEU	Secure HALEU fuel supply for research reactors and med. isotopes		1,1
SAVE	Action to improve security of supply of fuel for VVER NPPs		10
SCORPION	Development of materials for accident-tolerant fuels	X	2,6
TITANS	Tritium experiments and modelling in fusion and fission facilities		2,9
TRANSPARANT	Partitioning and transmutation of spent fuel and Myrrha development	X	5,4
Total			**45,6**

Source: European Commission

Most of the projects launched in 2022 are in their initial phase of implementation and the projects from 2023-2025 call started in second half of 2024. Independent experts[51] estimated that about **80% of the projects launched in 2022 are well-advanced and on track to be successful in the achievement of their goals**, consistent with the Euratom Work Programmes. The remaining projects show progress, however there are specific challenges due to lack of material test reactors in Europe, unclear goals for advanced systems reactor technology in the EU or the need for a re-orientation to keep up with developments in SMRs and advanced systems. The evaluation noted that Euratom-funded severe accident analyses and prevention work is world-class. For new reactor systems, early-stage safety and regulation issues were addressed but the need for greater involvement of experienced industrial partners in project coordination was emphasised. Experts also indicated areas where improvements are needed in the organisation of Euratom safety research[52]: (1) Cooperation at international level should be enhanced with a larger participation of entities from third countries and, when possible, due consideration of the analogous R&D work carried out by the IAEA and the OECD/NEA; (2) more efficient coordination between Euratom research actions and actions devoted to education

51 Ibidem.
52 Ibidem.

and training (ENEN2Plus project) and infrastructures (OFFERR project) is needed; (3) there is the need to improve risk assessment and risk management of the projects especially when experimental work is substantial. These recommendations will be implemented for on-going projects using flexibility allowed by the grant agreements.

Table 8 – Research projects for nuclear materials, data and innovation (grants in million Euro)			
Project	**Brief description**	**JRC**	**Grants**
APRENDE	Action to enhance nuclear data for modelling and simulation tools	X	4
iWeld	Development of non-destructive welding ultrasound inspection		1,2
NPHyCo	Innovation for H2 cogeneration at nuclear power plants	X	2
CONNECT-NM	Partnership to accelerate nuclear materials innovation for all reactors	X	20
INNUMAT	Innovative structural materials for fission and fusion reactors	X	7,8
Total			35

Source: European Commission

Results of the evaluation are also confirmed by public consultation (see Box 1).

Box 1 – Results of public consultation on safety research

- Regarding statement that the Euratom Programme 2021-2025 is making progress towards delivering its objectives in nuclear safety, 45% of respondents agreed, 19% strongly agreed, while 18% did not know, 10% were neutral, and 8% disagreed.
- When asked if during the 2026-2027 extension, the Euratom Programme should prioritise/deprioritise its support for nuclear safety, Essential role indicated 45% of respondent, high priority - 28%, medium priority - 16% of respondents.

In the area of nuclear reactor safety research, JRC's activities under the direct actions have focused primarily on design basis analysis and the study of materials and components for current light water reactors (LWR), SMR and advanced systems. For instance, experimental research on material degradation, complemented by analytical and numerical simulations aimed to assess component ageing and ultimately contribute to safety characterisation in view of long-term operation of current reactors, has been implemented. Results of this research are then integrated in practice and procedures for lifetime assessment of installations, service inspections and safety standards.

Studies conducted by the JRC on SMR design basis also aimed at identifying potential issues in view of licensing qualification for a technology that is attracting increasing attention in Europe. JRC's research focuses on several types of SMR concepts such as water, gas or molten salt cooled, which postulate enhanced safety features. These activities have been integrated with indirect actions guaranteeing enhanced synergies with the EU stakeholders involved.

In the area of fuel safety, JRC's experimental research mostly contributed to the analysis of fuel behaviour, including accident tolerant fuels (ATF), in a reactor during normal operation and under accident conditions. These studies are primarily enabled by

the use of JRC's nuclear research infrastructures and in close collaboration with a few EU Member States research institutions (CEA, NRG, SCK-CEN) through collaborative agreements. The JRC developed code TRANSURANUS is also used for behaviour modelling of fuel, and its access is readily shared with relevant stakeholders through fuel licensing processes. Overall, direct actions research in this field have underpinned the licencing of fuels and reactor systems, further contributing to improve nuclear safety.

Through the direct actions, specific policy support is also provided to partner DGs. The JRC supports DG ENER in the implementation of the Nuclear Safety Directive by reviewing the interpretation of its requirements and safety objectives and by participating in topical peer reviews such as the IAEA's Integrated Regulatory Review Service (IRRS) missions in EU Member States, as the Commission's observer. Another contribution is reflected in the European Clearinghouse network[53] managed by the JRC, which issues topical studies and provides data and analysis on incident cases, sharing knowledge and best practices to support European nuclear safety authorities. Technical and scientific expertise is also provided by JRC to DG INTPA for the management of projects in third countries funded under the INSC. Together, these activities play an important role in reinforcing nuclear safety standards in and outside of the EU.

Another notable contribution of the JRC to EU policy support and knowledge management during the period was the technical assessment of the environmental impact of nuclear energy[54] and its compatibility with the "do no significant harm" criterion in the context of the taxonomy regulation. The report released in 2021 contributed in large part to the scientific basis for the Complementary Climate Delegated Act, which included nuclear energy as a transitional activity towards climate neutrality.

The experts' evaluation of Euratom projects provided a **comprehensive set of recommendations for directions of research in nuclear systems** in view of the Programme's extension for 2026-2027 (see Box 2 below). Commission services agree that, as Member States extend the operational lifetimes of nuclear reactors, there is need for research on LTO, focusing on plant safety, material ageing, modelling and nuclear data. Collaborative projects with industry, regulators and their TSOs are essential, along with access to experimental infrastructures. However, LTO investments should be financed by the owners of the refurbished nuclear facilities. R&D on severe accidents at existing plants should be strengthened, with greater European coordination, to identify weaknesses in refurbished units and reduce uncertainties.

Box 2 – Experts recommendations for safety research *(excerpt)*

- **Maintaining the Programme scope and budget for fission research at the same level as they were in 2021-22 and 2023-25** would be the minimum to maintain the current capacities,

53 Clearinghouse - European Commission (europa.eu)

54 Abousahl, S., et al., Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation'), EUR 30777 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40538-2, doi:10.2760/207251, JRC125953.

to ensure safe operation of nuclear power plants in Europe and to be able to assess the new reactor technologies in terms of nuclear safety. Present scope and level of funding are however not sufficient if Europe has ambition to catch up with international competitors and to address the key issues for the development of SMRs, Advanced Modular Reactors (AMRs), advanced fuels and fuel cycles and to dramatically increase nuclear skills in the EU

- In many EU countries, there are programmes to extend the lifetime of operating NPPs, currently set at 40 to 60 years, up to 80 years. To address this challenge, the **Programme needs to further support the understanding of degradation and ageing of Gen-II and Gen-III NPPs.**
- **Preparation of the safety case for SMRs** and AMRs requires a wide range of research data as well as the verification and validation of simulation tools which are currently missing. The analysis of the most mature SMR and AMR designs, including in terms of fuel design, safety and security concepts, as well as proliferation resistance is essential to better inform Member States prior to deployment in Europe. These elements are on the critical path to licensing these advanced technologies and, therefore, the Euratom Programme should address these issues as early as possible.
- The area of nuclear fuel covers safety research on ATFs as well as development of European VVER fuels. There is the need to support both manufacturing and characterisation of fuels for licensing and operation. Attention should also be paid to fuel behaviour compliant with safety requirements, including for SMR. For the future, it will be necessary to **well-define ATF requirements and features. Establishing common criteria for ATFs would provide clear goals for the research.**
- The **needs of the EU's safety authorities for scientific data and validated tools to assess new reactor concept safety issues** are already recognised in the Euratom research goals but should be further emphasised in future actions, amongst others by systematically setting up end-user groups that gather representatives from both the relevant industries and the regulators and TSOs.

Source: Liisa Heikinheimo, Stefano Monti, Interim evaluation(…)

4.1.3. Safe spent fuel and radioactive waste management, decommissioning

A co-funded European Partnership **EURAD-2**[55] is the **main Euratom action for supporting radioactive waste management in the EU** accompanied by smaller projects (see table 9) and JRC direct actions. EURAD-2 builds on the achievements of the EURAD European Joint Programme, completed in 2024 and funded by the Euratom Programme 2014-2020. As highlighted by the ex-post evaluation of 2014-2020 Programme[56], EURAD's joint programming allowed to foster cooperation between 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. EURAD had achieved important objectives such as generation of

[55] For more details see EURAD-2 website https://www.ejp-eurad.eu/ as well as CORDIS website on this project https://cordis.europa.eu/project/id/101166718

[56] Commission report on ex-post evaluation of Euratom Research and Training Programme 2014-2020, COM(2024)549 accompanied by SWD(2024)272 https://eur-lex.europa.eu/legal-content/FR/TXT/?uri=COM:2024:549:FIN

new or deeper scientific knowledge, and transfer of knowledge and experience from Member States that are in an advanced stage of expertise and implementation to those that are only starting to develop management methods and disposal facilities, helping fulfil the requirements set by Directive 2011/70/Euratom ('Waste Directive')[57]. Another important EURAD's accomplishment is the transfer of knowledge between generations, in particular through the specialised training and the funding of 132 PhD students[58].

Table 9 – Euratom projects in radioactive waste management and decommissioning (million euro)			
Project	**Brief description**	**JRC**	**Grants**
EURAD-2	Co-funded European Partnership for radioactive waste management	X	20
HARPERS	Development of harmonised application of the international regulatory framework for nuclear waste management	X	2,5
DORADO	Development of AI-based robot assisted decommissioning applications		1,9
XS-ABILITY	Advanced robotic solutions to investigate hard-to-access areas and characterise difficult-to-measure radionuclides.		2
Total			26,4

Source: European Commission

Results of independent evaluation - according to the proposal for Partnership evaluated by independent experts, the EURAD-2 will address the large inventory of radioactive waste across European Union Member States, with a comprehensive approach covering all materials from very-low-level and low-level waste (> 90%) through high-level waste (0.2% in volume). The partnership should produce better technologies and tools, enabling Member States to demonstrate their developments in safe waste management practices for surface, shallow and deep geological disposal facilities, as well as pre-disposal and interim storage. The priorities for each Member State depend notably upon the national radioactive waste inventory, host rock geology, national context and legislation, and the stage of the national programme's lifecycle - with priorities changing as the programme progresses. Key role of EURAD-2 and its potential impacts are underlined by the evaluation[59], which also emphasised the need to keep adapting the Partnership to the evolving situation (see box 3 below).

Box 3 – Findings from independent evaluation of EURAD and EURAD-2 *(excerpt)*

– The **vision and goals of EURAD-2 are clearly entirely valid but they must be adapted to the current radioactive waste management situation** as experienced by the Member States and the national programmes.

57 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.

58 https://www.ejp-eurad.eu/news/eurad-numbers

59 Jean-Paul Minon, *Interim evaluation of Euratom Programme 2021-2025 and ex-ante evaluation of Euratom Programme 2026-2027 in the field of spent fuel and radioactive waste management*, March 2024

- Consequently, the Member States and end-users should clearly formulate their needs and make the logic and rationale of the joint research programme consistent with the diverse state of development of the national programmes.
- The **Commission should ensure that the governance of the Partnership is adapted** to enable this process to take place in full transparency at an early stage in the development of its programme of research actions, guaranteeing a real European added value towards the implementation of safe RWM and disposal across the EU.
- In light of the EURAD success, and the call for greater inclusivity by welcoming new entities, in particular from underrepresented Member States, **the EURAD-2 grant of 20 million euro proves insufficient to ensure the success of Joint Programming** and to effectively address the upcoming challenges facing the community […].

Source: Jean-Paul Minon, Interim evaluation (…)

Commission's assessment of EURAD-2 – Commission is responsible for steering EURAD-2 work in line with the Euratom Work Programme 2023-2025[60]. The Partnership will need to: (1) build on the structure, network and tools that EURAD EJP has established to maintain a sound and efficient knowledge management system; (2) improve, innovate and develop science and technology for the management and disposal of radioactive waste and address the different radioactive waste streams; (3) consolidate the knowledge for a safe start to operating the first geological disposal facilities and support all Member States' national programmes in line with the requirements under Directive 2011/70/Euratom and Commission report COM(2017)236; (4) provide input to the next set of Member States with mature site selection programmes, and thus with construction and operation in sight, in order to promote broadly accepted industrialisation of nuclear waste disposal in the EU.

More efforts should also be made to engage regulators in EURAD-2 work, in formats and ways that are suitable for the range of regulators in different Member States with their various country specific arrangements. Knowledge management is also important for regulators since regulatory organisations have fewer staff members and may be vulnerable during periods of increased staff turnover. Partnership's action should also be linked to the results of monitoring the implementation of the Waste Directive by Member States.

Regarding funding for EURAD-2, the Commission indicated in the Euratom Work Programme 2023-2025[61] that it envisages providing top-up funding to the Partnership, to be determined later, subject to adoption by the Council of a Regulation establishing the Euratom Research and Training Programme 2026-2027, and adoption of the Euratom Work Programme 2026-2027.

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60 See pages 63-73 in the Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

61 See footnote 82 in the Euratom Work Programme 2023-2025 (C(2024)3263) https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

Box 4 - Public consultation on Euratom research for radioactive waste management

11% of respondents strongly agreed, and 36% agreed that the Euratom Programme 2021-2025 is **making progress towards delivering its objectives in RWM**. 7% disagreed and 1% strongly disagreed with the statement. 31% of respondents did not know, while 15% were neutral.

JRC's direct actions research carried out in 2021-2024 contributed to investigating and improving characterisation of conventional fuels, including ATF and other compounds for innovative systems, in view of the safe and cost-effective management of interim and long-term storage, transportation and disposal of spent fuel. Other radioactive waste forms, including actinides and their recycling, are investigated in the JRC's unique testing facilities. Research also comprised studies, in collaboration with IRSN, on the properties and ageing behaviour of corium generated under severe accident conditions, especially relevant for the remediation processes of the Fukushima Daiichi site. The JRC actions in this area are also strongly aligned with the research conducted within the European partnerships EURAD and EURAD-2 in which the JRC participates.

In support to the implementation and monitoring of the safe management of spent fuel and radioactive waste directive, the JRC provides expert reviews of EU Member States national programmes and reports, contributing largely to the Commission's report on implementation. This policy support activity gives an essential and comprehensive overview of the various national situations in the EU and allows the identification of challenges and weak points in national policies and programmes. The JRC also supports the implementation of Directive 2006/117 Euratom on shipments of radioactive waste and spent fuel by elaborating a detailed analysis of shipments, trends and challenges of imports, exports and transits in the EU based on the corresponding national reports submitted by the Member States to the Commission. In the framework of the IAEA's Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) missions in EU Member States, JRC participates in the peer-review as observer and provides feedback to DG ENER and IAEA.

4.1.4. Ionising radiation applications and protection

Outputs 2021-2023					
23	**27%**	**41**	**69**	**>500**	**212**
Member States involved in PIANOFORTE co-funded European Partnership	of Euratom grants awarded for R&D in non-power applications of ionising radiation	researchers granted mobility support	PhD, Post-Doc and MSc students involved in Partnership and projects	Patients treated between 2021 and 2024 with Targeted Alpha Therapy developed by the JRC	Participants in trainings by PIANOFORTE

Broad portfolio of actions addressing radiation protection - during four years of the Programme's implementation the Commission launched PIANOFORTE, a co-funded European Partnership for radiation protection research, complemented by eight research projects in medical applications ionising radiation, supply of radioisotopes and alternative applications of nuclear technologies for a total amount of EUR 50 million (see table 10). JRC supports four of these projects by providing a specialised know-how and infrastructures. It also carries out its own research in this field (using 17% of total resources), pioneering the development of a novel type of radionuclide treatment with targeted alpha therapy, supporting standardisation efforts, the optimisation of clinical practices and knowledge transfer, as well as radioactivity environmental monitoring.

Table 10: Overview of Euratom-funded research projects in radiation applications and protection

Project	Description	JRC	Grants (million EUR)
PIANOFORTE	Research for protection of the public, workers, patients and the environment from environmental, occupational and medical exposure to ionising radiation.		29,5
SECURE	Development of alternative technologies for production of therapeutic radionuclides (selected alpha and beta emitting isotopes) for improved patient treatment	X	3,6
TETRIS	Development of risk assessment tools (biological extended models and digital twins) for severe side effects after breast radiotherapy		3,5
PARCOVAL	Investigation of a potential of palladium extracted from spent nuclear fuel as a catalyst to convert CO2 from industry into CO, and to produce chemical intermediates to manufacture pharmaceuticals and esters.	X	2,9
NUCLIM	Climate science research using radon as an atmospheric tracer to provide a precise baseline for European greenhouse gas levels and assist in environmental studies.		2,6
MaLaR	Development of technology for the selective recovery of rare-earth metals (lanthanides) from nuclear waste.		2,3
artEmis	Development of smart sensor system to monitor radon levels in earthquake-prone regions of Europe, as a potential precursor for earthquakes and volcano eruptions.	X	2
RADOV	Project aims to apply radiation from accelerators to produce bioactive peptides from different food proteins to use as nutraceuticals.		2
PULSAR	Development of radioisotope power systems as enabling technology for deep space exploration, using plutonium-238 and Stirling engine.	X	1,8
Total			50,2

Source: European Commission

First results of PIANOFORTE and other projects - Euratom support for research in radiation protection is centred around the PIANOFORTE Partnership (59% of all funding), a long-term partnership (2022-2027) which is based on experience and outcomes of CONCERT European Joint Programme supported by Euratom in 2015-2020.

According to project monitoring[62] and independent evaluation[63], PIANOFORTE should substantially expand scientific knowledge that supports implementation of the Basic Safety Standards Directive and helps to harmonise radiation protection practices throughout Europe. It should also lead to advances in radiobiology and in developing tools, methods and best practices to cope with issues related to radiation exposure. Partnership supports research through competitive open calls, and call priorities are set in a consensual process to align them with the priorities of participating Member States and radiation protection stakeholders. The first 2023 call attracted 23 proposals and resulted in 9 projects[64] with a total funding of EUR 13 million involving 86 entities in 3 topical areas (understanding of disease pathogenesis of ionising radiation-induced cancer, optimisation of the benefit/risk ratio for diagnostic and therapeutic procedures; radiation protection from threats due to war or armed conflicts or natural disasters). The selected projects are addressing areas such as the implementation of personal and real-time dosimetry, advancements in the diagnosis and treatment of breast cancer, management of pregnant patients. While still in the initial phase (all started in 2024), independent evaluation indicates[65] that these projects are highly relevant for improving health care when using ionising radiation in line with the BSS requirements. The third topic on radiation protection threats due to war or armed conflicts or natural disasters became relevant in light of the ongoing war in Ukraine and the associated concerns regarding the potential use of nuclear weapon. All three selected projects for this topic should bridge the knowledge gap regarding consequences stemming from armed conflicts. PIANOFORTE also provided an analysis of modern proton therapy for the European Investment Bank[66]. PIANOFORTE plays significant role in maintaining competences by involving 69 PhD, post-doc and MSc students, and providing mobility support scheme (41 researchers supported). It also organises training courses to enhance competences in radiation protection and related fields.

Topics in 2021 and 2023 call for proposals concerning supply of radioisotopes, innovation in radiation protection and new applications of nuclear technologies attracted 24 proposals and the Commission was able to fund 8 projects, with 5 proposals left on reserve list, which would require additional EUR 16 million of funding. Strong interest of stakeholders and substantial number of newcomers brought by accepted projects show potential for innovative ionising radiation applications. This potential could be further realised in synergy with actions funded under Horizon Europe as indicated by recommendations from STC and experts.

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62 For more details see https://cordis.europa.eu/project/id/101061037/results

63 Helena Janžekovič, *Interim Evaluation and Ex-ante Evaluation for Euratom in the Field of Radiation Protection*, June 2024.

64 For more details https://pianoforte-partnership.eu/research-projects

65 Helena Janžekovič, *Interim Evaluation and Ex-ante Evaluation for Euratom in the Field of Radiation Protection*, June 2024.

66 Report with the review on recommended clinical and research practices in modern proton therapy - https://pianoforte-partnership.eu/web_object/d37.pdf

An independent evaluation[67] concluded that, in addition to PIANOFORTE, other Euratom-funded projects in this area (see table 10), some of which are also supported by JRC's expertise and infrastructures, will contribute to better treatment of cancer patients, and as such should provide support to operators and regulators in the medical area, along with other stakeholders such as laboratories and suppliers. They will also foster innovation and contribute to advancements in the supply chain for new radiopharmaceuticals and equipment for detection of ionising radiation. In particular, SECURE project[68] is going to decrease EU's dependence on source material and expertise from the third countries.

The added value of the JRC's research into non-power applications of ionising radiations has been highlighted by the external evaluation of experts. Particularly in the medical field, the JRC dedicates its research to the development of radionuclides, with the pioneering of targeted alpha therapy using actinium-225 for the treatment of prostate cancer[69]. Since 2021, two specific projects have been implemented, resulting in collaboration with hospitals, cancer research centres and international organisations around the development of alpha-emitters for therapeutic use in oncology. The JRC also explores novel production paths for ac-225, as part of collective Commission efforts under the Strategic Agenda of Medical Ionising Radiation Applications (SAMIRA)[70] action plan to support security of supply of medical radionuclides in the EU and therefore contribute to strategic autonomy in this field. The effectiveness of JRC's research on targeted alpha therapy can be attested by the 42 related peer-reviewed publications since 2021, three of which feature amongst the JRC's five most cited scholarly publications in the nuclear research field. Two of these papers also received the EANM Springer Prize award in 2023 and 2024[71].

STC review of Euratom actions in radiation applications and protection – the Euratom Scientific and Technical Committee (STC) reviewed PIANOFORTE and acknowledged the progress made by the Partnership in advancing radiation protection research in Europe. It also provided number of recommendations for improvements during the extension (see box 5 below), which underline the need for improvements and simplification of the Partnerships organisation. The Commission services emphasise that to effectively address key challenges, PIANOFORTE needs to further develop open calls with relevant topics and maintain a mechanism for integrating new participants through these calls.

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67 Ibidem

68 For more details https://cordis.europa.eu/project/id/101061230

69 For more details: https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/alpha-emitters-based-therapy-prolongs-life-patients-advanced-prostate-cancer-2024-04-26_en

70 Commission Staff Working Document on a Strategic Agenda for Medical Ionising Radiation Applications (SAMIRA), SWD (2021)14, https://energy.ec.europa.eu/system/files/2021-02/swd_strategic_agenda_for_medical_ionising_radiation_applications_samira_0.pdf

71 The two awarded publications: Sathekge, M., Bruchertseifer, F., Knoesen, O. et al. 225Ac-PSMA-617 in chemotherapy-naive patients with advanced prostate cancer: a pilot study. Eur J Nucl Med Mol Imaging 46, 129–138 (2019) and Handula M, Beekman S, et al. First preclinical evaluation of [225Ac]Ac-DOTA-JR11 and comparison with [177Lu]Lu-DOTA-JR11, alpha versus beta radionuclide therapy of NETs. EJNMMI Radiopharm Chem. 2023 Jun 30;8(1):13.

Development of PIANOFORTE collaboration with Horizon's Partnerships will require further support from the Commission.

Box 5 - STC recommendations for PIANOFORTE co-funded European Partnership

1. Further **improvements in the Partnership's organisation** and operations are needed to ensure Euratom-funded research stays relevant and addresses pressing societal challenges.
2. **Enhancements in stakeholder networking** are needed to incorporate the long-term perspectives of diverse stakeholders in a susta inable manner.
3. **Simplification of the application process** is recommended to increase involvement of universities and hospitals.
4. To advance understanding of risks of ionising radiation, PIANOFORTE should take advantage of transdisciplinary approaches by establishing a **dedicated funding mechanism in collaboration with HE partnerships and clusters** where radiation protection is relevant, such as health, energy-climate, civil security, space (including ESA), and environment.
5. The STC emphasises the **importance of co-funding various dynamic research types** according to specific topics and ensuring suitable funding through open calls.

Source: Report from STC working group 1 on radiation protection and non-power applications

An independent expert commissioned for the interim evaluation provided further recommendations for Euratom actions in radiation applications and protection (see Box 6). Some are relevant for the PIANOFORTE, which could carry out a systematic analysis of relevant national programmes as part of the call preparation process. Launch of the Euratom calls for proposals outside the Partnership, in particular in the area of medical radioisotopes, will depend on the consultation with stakeholders, Programme Committee as well the outcome of on-going work under SAMIRA[72].

Box 6 – Recommendations from independent experts

- The Commission should **continue launching large projects addressing specific challenges**, in particular for strategic autonomy in supply of radioisotopes, while maintaining PIANOFORTE to advance radiation protection research with due attention to not duplicate research already covered by the Partnership.
- The Commission should **continue launching calls for proposals with broad topics** in radiation applications and protection, attracting the newcomers and innovative ideas that extend beyond the scope of the roadmaps established by PIANOFORTE and EURAD.
- A **systematic analysis of national programmes** may reveal new elements of research landscape related to radiation protection, non-power applications, and, where relevant, the nuclear research arena in Member States in the coming year. The outcomes of such an analysis could support the establishment of future Euratom programmes and calls.
- **Synergies with several other areas beyond classical radiation and nuclear field should be also encouraged**, e.g. development and technological transfer of state-of-the-art medical equipment supporting justification and optimisation. As such Euratom actions could be linked to other research areas, e.g. health screening programmes. Unnecessary duplication should be avoided, and clear mechanism should be in place that scientists from several different disciplines are coming together and cooperate. […] The mechanism should clearly be focused on specific goals, e.g. development of measurement equipment based on European technology

[72] For more details https://energy.ec.europa.eu/topics/nuclear-energy/radiological-and-nuclear-technology-health/samira-action-plan_en

for quality assurance and control in medical exposure in screening programmes and nuclear medicine or development of measurements of radon.

Source: Helena Janžekovič, Interim Evaluation (…). Note: text of recomendations amended for clarity.

The direct actions also participate in the development of non-power applications of radionuclides for space exploration. JRC's research in americium oxide stabilisation as an alternative to plutonium-238 currently imported from Russian, has contributed to the design basis for a future radioisotope power source retained by the European Space Agency (ESA). Since 2022, the Euratom-funded PULSAR project, which includes JRC's participation, also aims to build-up a European production capacity and radioisotope power source based on plutonium-238.

JRC also provides scientific and technical support for continued development and maintenance of the EU emergency information exchange systems like the European Community Urgent Radiological Information Exchange (ECURIE)[73], the official information exchange network for early notification of nuclear accident by Member States, which contributes to reinforce nuclear emergency preparedness and response in the EU. Additionally, the JRC has developed a tool for diagnosis and prognosis of hazards in nuclear emergencies (DAPHNE), which provided numerical simulation to evaluate accident scenarios and radiological dispersion. The tool has been extensively used in support for Ukraine, producing a clear assessment of radiological risks for nuclear power plants under wartime conditions. In complement to these activities, the JRC contributes significantly to enhancing environmental monitoring and radiation protection. It manages the European Radiological Data Exchange Platform (EURDEP)[74], which provides real time information about environmental radioactivity in EU Member States and the Radioactivity Environmental Monitoring database (REMdb)[75], which stores data gathered since 1980's. JRC's research in this area also comprised the provision of reference materials for hundreds of laboratories in the EU and the conduct of proficiency tests in over 100 facilities in Member States on environmental monitoring. On the whole, the combination of expertise on emergency information exchange, atmospheric dispersion forecast, and radioactivity monitoring allows the JRC's work to underpin decision-making process in the event of a radiological accident and to establish best practices and optimise measurements and standards.

In conclusion, research actions launched and carried out by the Commission under 2021-2025 Programme cover all areas of ionising radiation applications and protection set out in the Council Regulation. PIANOFORTE made a satisfactory progress and involved beneficiaries from most of the Member States and from non-EU countries. Open calls organised by the Partnership allow for including new participants. Available results show that Euratom projects should substantially expand scientific knowledge that supports

73 87/600/Euratom: Council Decision of 14 December 1987 on Community arrangements for the early exchange of information in the event of a radiological emergency

74 https://remon.jrc.ec.europa.eu/About/Rad-Data-Exchange

75 https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/REMdb

implementation of the Basic Safety Standards Directive and helps to harmonise radiation protection practices throughout Europe. It will also provide insights into innovative and optimised medical procedures and their effective transfer into clinical practice. Euratom projects concerning innovative applications of ionising radiation in circular economy, deep space exploration and environmental monitoring show potential for supporting EU competitiveness and strategic autonomy.

Evaluation also indicated areas of concern: (1) the need for simplification of Partnership's administration and calls; (2) lack of real synergies with other EU programmes, in particular Horizon Europe, which could expand membership of the Partnership and its scope.

4.1.5. Nuclear security, safeguards and non-proliferation

Outputs 2021-2024			
76	**13**	**200-400**	**5**
Trainings in nuclear security and safeguards delivered through the EUSECTRA	Remote e-learning courses developed by JRC during the COVID-19 pandemic	People from Member States, the European Commission and partner countries trained on average every year through the EUSECTRA	Yearly agreements in force between JRC and partner DGs to provide services in support to EU safeguards

According to the Council regulation, the JRC is responsible for strengthening EU nuclear security and nuclear safeguards, including non-proliferation aspects and research into combatting illicit trafficking and nuclear forensics. JRC uses about 22% of resources for Euratom direct actions in this field.

The JRC's research provides expertise, R&D, tools, technologies and approaches to increase the efficiency and effectiveness of the implementation of Euratom based safeguards obligations in the EU. The JRC carries out essential tasks in the area of Euratom safeguards and non-proliferation, such as R&D of methods and concepts for safeguards analytical measurements, with a view to reduce uncertainty and increase result precision. This involves the development of instrumental upgrades and advanced software and the application of artificial intelligence for data evaluation. Improved measurement techniques and results led to further verification credibility for safeguards inspectors and enhanced inspection efficiency. JRC's research also focused on advanced verification technologies and equipment for containment and surveillance, sealing, localisation technologies and novel approaches for secure data transfer. The development of those methods and verification technologies established the JRC as a key player in the monitoring and prevention of nuclear proliferation. JRC also dedicates a substantial amount of nuclear safeguards research in support to the IAEA, under the EC Support

Programme to the IAEA safeguards[76] in close interaction with other support programmes of EU Member States and international partners.

The JRC supports the European Commission in the project management activities under the Neighbourhood, Development and International Cooperation Instrument[77], including by contributing to the steering, development, implementation and coordination of CBRN risk mitigation actions. On nuclear security, the JRC is involved in capacity building activities outside Europe, in support to DG INTPA and the Foreign Policy Instruments service of the Commission. In the frame of the CBRN (Chemical, Biological, Radiological and Nuclear) Centres of Excellence[78], the JRC supports the implementation of nuclear security related projects to strengthen mitigation and preparedness capacities against CBRN risks in various countries, e.g. Ukraine, Moldova, Georgia or Azerbaijan, as well as nuclear forensic activities in Armenia and the Western Balkans. Specifically in the area of nuclear forensic, research focused on the continuous development of characteristic parameters and analytical methods, providing a solid scientific basis and enabling the JRC to directly support Member States and international organisations like the IAEA with the analysis of samples, the provision of reference materials and the participation in virtual exercises. All these activities contribute to the Security Union, reinforcing capacities of national authorities in and outside the EU, as well as the European Commission, to deal with nuclear security threats and properly respond to incidents.

The JRC also contributes to improved strategic trade control activities to support the EU response to the risk of proliferation of weapons of mass destruction and improving nuclear forensic techniques and material databases. In support to DG Trade, JRC's expertise has been extensively used in dual use export control analysis to define and monitor compliance with the waves of sanctions against Russia.

Through the direct actions, the JRC develops and provides training courses on nuclear safeguards and nuclear security to front line officers and law enforcement bodies of the EU Member States and collaborating third countries through the European Nuclear Security Training Centre (EUSECTRA)[79]. Those trainings have resulted in capacity building for Euratom safeguards inspectors. The EUSECTRA, managed by the JRC, is a valuable complement to Member States training capabilities, particularly for detection of nuclear and radioactive material, as participants have the opportunity to train with nuclear and radioactive materials embedded in realistic scenarios. During the COVID-19 pandemic, necessary restrictions to nuclear infrastructure led to the development of interactive remote e-learning courses, with 2 sessions in 2021 and 11 in

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76 https://www.iaea.org/topics/safeguards-and-verification/programmes/member-states-support-programmes

77 Regulation (EU) 2021/947 of the European Parliament and of the Council of 9 June 2021 establishing the Neighbourhood, Development and International Cooperation Instrument – Global Europe

78 https://cbrn-risk-mitigation.network.europa.eu/eu-cbrn-centres-excellence_en

79 For more details - https://joint-research-centre.ec.europa.eu/laboratories-z/european-nuclear-security-training-centre/about-eusectra_en

2022. Since 2021, 76 training sessions were delivered to nuclear inspectors and frontline officers from the European Commission and Member States, including third countries, in a sustained effort to support capacity building and training in this field. At the urgent request of Ukrainian authorities, EUSECTRA also joined efforts with the US and Interpol to organise a joint training on radiological crime scene management for Ukrainian law enforcement officers.

Moreover, the JRC provides technical and scientific expertise in support to policy implementation in the areas of nuclear security and safeguard through capacity building, consulting and training activities. This directly supports the Euratom safeguards inspectors of DG ENER and the IAEA, as part of the European Commission Support Programme (EC-SP). For instance, the JRC performs in-field measurements, using the mobile COMPUCEA instrument during physical inventory verification at uranium fuel production facilities. This exercise carried out in Spain and Sweden during the evaluated period, was done jointly with DG ENER and IAEA inspectors. The JRC also assures operational support at the on-site laboratory (LSS) of the reprocessing facility of La Hague in France at the request of DG ENER. Support activities comprise timely analysis of highly radioactive samples taken for safeguards purposes, transportation of swipe samples for particle analysis at the JRC Karlsruhe site and the provision, certification, and delivery of reference materials. These analytical results and scientific products directly support the Commission's obligations in relation to nuclear safeguards. They constitute an essential input for DG ENER's annual safeguards implementation report and form part of the active cooperation and analytical support to the IAEA. Overall, this ensures non-proliferation of nuclear material and detection and prevention of illegal acts. Interim evaluation provided recommendations for improving JRC actions in this field which will be implemented during the extension of the Programme (see Box 6).

Box 6 – Recommendations from evaluation of JRC activities by panel of experts

- The JRC should contribute to **analysing the security concepts and proliferation resistance of SMR/AMR designs** to better inform Member States and the European Commission in view of their deployment.
- The JRC's contribution is especially valuable in the area of **training on CBRN threats** and should be maintained.
- **Cutting-edge R&D in nuclear safeguards is still needed** to further improve methodologies, test new technologies or materials and detect and counter potential new pathways of diversion.
- Ways should be found to **better communicate about JRC safeguards activities**, especially emphasising their impact for worldwide peace and security.

Source: Heuer, R. et al., Interim evaluation of the activities of the Joint Research Centre (…)

4.1.6. Nuclear data radioactivity measurements and standardisation

Outputs 2021-2024			
22	**14**	**9**	**21**
Reference materials delivered by JRC	Reference methods and measurements validated by JRC laboratories	JRC contributions to nuclear standards	Scientific information systems, databases and dataset collections provided by JRC

Largely contributing to support nuclear security and safeguards, but also nuclear safety, the JRC provides reference data, materials and measurements for harmonisation and standardisation[80]. Nuclear applications require reliable nuclear data to validate physical models on which are based subsequent engineering developments and licensing requirements. The provision of nuclear data by the JRC feeds European and international libraries such as the Joint Evaluated Fission and Fusion library hosted by the OECD-Nuclear Energy Agency (NEA)[81] and are used as reference for nuclear standards. Similarly, JRC also provides accurate decay data, which has been integrated in both the Decay Data Evaluation Project (DDEP) and the Evaluated Nuclear Structure Data File (ENSDF)[82] libraries. This data contributes to establish decay characteristics of radionuclides, relevant for nuclear medicine, environmental monitoring, nuclear safety, security, safeguards and nuclear waste management. Finally, JRC's expertise in metrology leads to the production of certified nuclear reference materials, reference measurements and conformity assessment tools, all used as quality assurance instruments to improve nuclear safety, security and safeguards.

80 Point (b)(vi) of Council Regulation 2021/765 states that: '*for fostering nuclear science as a base to support standardisation, direct actions will provide state-of-the-art reference data, materials and measurements related to nuclear safety, safeguards and security, as well as other applications as nuclear medicine*'

81 JEFF Nuclear Data Library - NEA (oecd-nea.org)

82 Evaluated Nuclear Structure Data File | IAEA

4.1.7. Maintaining and further developing expertise and competence in the nuclear field

Outputs 2021-2024					
3324	**962**	**190**	**167**	**150**	**12**
People trained by JRC since 2021	PhD/MSc students and researchers benefitted from mobility support from Euratom projects	Number of researchers who had access to JRC nuclear infrastructures to conduct experiments	PhD, Post-Doc and MSc students supported in fission projects and Partnerships launched	researchers supported to carry out experiments in 24 research facilities (OFFERR)	Post-doc MSCA fellowships awarded with Euratom funding

Under the 2021-2025 Programme, the Commission launched number of actions for developing expertise and competencies in nuclear field. These actions provide specialised training, access to research infrastructure, support researchers' mobility and studies at MSc, PhD and post-doc level.

In nuclear fission, the Commission provided trainings and mobility opportunities via various JRC initiatives as well as long-term indirect actions, offering support to students and researchers and bringing stability and predictability for stakeholders and users. Other Euratom actions concerned promotion of innovation in nuclear research, knowledge management and support for technology transfer from the research to industry. Assessment of progress made in each field specified by the Council regulation[83] is explained below on the basis of available reporting and assessment by independent experts. Education and training actions for fusion energy are discussed in section 4.1.8.

4.1.7.1. Support for education, training and mobility

In the field of nuclear fission, **support for PhD students is provided through research projects** giving financial assistance, hands-on experience and mentoring - currently 105 PhD students are involved in 30 projects launched in 2022[84]. More PhD students will be supported through 20 projects launched in 2024. Co-funded Partnerships also play

[83] Point (b) of Annex I to Council Regulation 2021/765

[84] Data from periodic reports submitted by projects.

significant role - PIANOFORTE[85] supports 40 PhDs and Post-Doc researchers. EURAD-2[86], launched in October 2024 is also expected to provide substantial support as its predecessor supported 132 PhD students.

ENEN2Plus project (2022-2026, grant of 6.8 million euro)[87] is the **main Euratom instrument for supporting mobility** in nuclear field. 921 students have been supported until September 2024, mainly through MSc internships, study exchanges and PhD research visits. This action is supplemented by specific mobility actions of the Euratom Partnerships in radiation protection (41 travel grants under PIANOFORTE) and radioactive waste management (95 mobility grants under EURAD (2019-2024).

With 3324 persons trained since 2021, JRC is one of the main providers of specialised training in nuclear field. During 2021-2024 about 18% of all direct actions were focused on knowledge management, education and training activities. Over the reporting period, the JRC has deployed 119 training courses for students and professionals from EU Member States and Commission services in presence, online or in hybrid format[88] in the areas of nuclear safety, nuclear security and safeguards (including for Euratom inspectors), strategic trade control, nuclear decommissioning and waste management and nuclear non-power applications. For nuclear safeguards and security in particular, 76 trainings delivered since 2021 have resulted in capacity building for nuclear inspectors and frontline officers[89]. JRC also provided, jointly with US and Interpol, training on radiological crime scene management for Ukrainian law enforcement officers.

In relation to the **assessment of skills and competences in nuclear field in EU**, the JRC operates the European Human Resources Observatory in the Nuclear sector (EHRO-N)[90] to provide methods and analysis of the nuclear workforce capabilities and needs in the EU, as well as long term prospects. In 2021-2024 EHRO-N has focused its activities on national nuclear workforce assessment and the analysis of human resources supply based on the European higher nuclear education offer in the EU[91]. These results, as well as the offer of support and methodology, help EU Member States to produce their own national

85 https://pianoforte-partnership.eu/training-education/competence-building

86 https://euradschool.eu/

87 https://www.enen2plus.eu/home and https://cordis.europa.eu/project/id/101061677

88 Eirini Michailidou, et al., Nuclear education and training activities of the Joint Research Centre of the European Commission: Maintaining and enhancing nuclear skills and competences, Nuclear Engineering and Design, Volume 423, 2024, 113087, ISSN 0029-5493

89 The European Nuclear Security Training centre (EUSECTRA), managed by the JRC, is a valuable complement to Member States training capabilities, particularly for detection of nuclear and radioactive material, as participants have the opportunity to train with nuclear and radioactive materials embedded in realistic scenarios. See https://joint-research-centre.ec.europa.eu/laboratories-z/european-nuclear-security-training-centre_en

90 EHRO-N - European Commission (europa.eu)

91 ERIKSSON, A. and ERIKSEN, B. Job Classification and Taxonomy in the Nuclear Sector, European Commission, Petten, JRC132572. EHRON reports are available at https://joint-research-centre.ec.europa.eu/ehro-n/documents_en

assessment of the needs and supply of nuclear skills. The JRC's work in this area remains strongly connected with the relevant stakeholders through the participation in the ENEN2Plus project. ENEN2Plus also prepared studies[92] on human resources needs in nuclear research and non-power applications, as well as a report on benchmarking existing E&T programmes.

Euratom financial support for MSCA post-doc fellowships resulted in 12 grants – 7 in fusion and 5 in fission – awarded during the first three MSCA calls supported by the Programme (i.e. the 2021, 2022 and 2023 MSCA calls). Three more grants and 5 Seals of Excellence are expected to be awarded to nuclear researchers for the 2024 call.

The number of fellowships supported by Euratom are still too low to discern trends. However, applicants in nuclear field appear to have a good success rate (38%) in comparison to that of MSCAs in general (15.8% for the 2023 call). There might be room for improvement in the number of applications and awarded grants, especially as, it would seem, many nuclear researchers are not yet aware of their eligibility to the MSCAs. While awarded fellowships in the 2021-2023 calls consumed 73% of the EUR 3 million initially budgeted, flexible arrangements allow for using Euratom funding over coming years. Limited Euratom budget did not allow to launch other MSCA actions such as Doctoral networks.

While the 2021-2025 Programme focused resources on larger and longer-term actions (OFFERR, ENEN2Plus, Partnerships), in complement to the JRC direct actions in education and training, stakeholders and Member States underlined the urgent need to address more thoroughly the lack of specialised skills in nuclear technologies and the radiological field in the EU's workforce. The Commission launched in 2024 a **European Nuclear Skills Initiative[93],** which provides for preparing and testing a strategy, drawing on approaches from different industries, the European Human Resources Observatory for the Nuclear Sector (EHRO-N) and Member States. The strategy should enable the development of skills necessary for EU strategic autonomy in the nuclear field and for the safe use of current and future nuclear technologies. This includes Small Modular Reactors (SMRs), which is why the call topic mentions that the strategy should also cover aspects relevant to the recently established SMR Industrial Alliance.

92 https://www.enen2plus.eu/documents

93 Call topic - HORIZON-EURATOM-2024-NRT-01-02, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/HORIZON-EURATOM-2024-NRT-01-02?order=DESC&pageNumber=1&pageSize=100&sortBy=relevance&keywords=Euratom&isExactMatch=true

4.1.7.2. Promotion of innovation, knowledge management, dissemination and exploitation of nuclear science and technology;

The Commission uses **recognition prizes to promote innovation in nuclear field**. Two editions of SOFT Prize in fusion energy between 2022[94] and 2024[95] saw a steady increase of in quality of applications from outstanding researchers or companies trying to find novel solutions, possibly with broader applications, to the challenges of fusion development. The winner researchers get 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. Following success of SOFT innovation prize, the Commission **expanded scope of recognition prizes under the current Programme to cover fission research**. The Nuclear Innovation Prize aims to stimulate the fission research community to strengthen innovation and foster an entrepreneurial culture in fission research. In 2022, the prize was awarded in 2 categories – safety of nuclear systems and safety of radioactive waste management[96]. The European Commission received 28 proposals that were evaluated by an independent jury composed of experts in technology transfer from business and academia. In nuclear safety, prizes were awarded for new cladding for nuclear fuel, development of new safety monitoring system for reactors, improved modelling of reactors, development of passive safety system for SMRs for district heating. In radioactive waste management, prizes were awarded for innovative methods for non-destructive waste characterisation, robotic solutions for cleaning and reducing radiation exposure. 2025 edition of the Nuclear Innovation Prize also covers radiation protection[97].

Knowledge management is supported via JRC actions and by European Partnerships, EURAD-2[98] and EUROfusion in particular. Specific attention has been dedicated by JRC to knowledge management, leading to defining and implementing a methodology of regular horizon scanning for nuclear foresight with the involvement of partner policy DGs[99]. Additionally, in the frame of a pilot action on knowledge management in the area of nuclear safety (PIKNUS)[100], the JRC has been developing a collaborative web-platform

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94 For details about 2022 edition of SOFT Prize see https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/soft-innovation-prize-three-researchers-awarded-2022-09-19_en

95 https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/three-outstanding-projects-win-2024-fusion-innovation-prizes-2024-09-25_en

96 For more details see https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/nuclear-innovation-prize-seven-applications-awarded-2022-05-31_en

97 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/prizes/nuclear-innovation-prize_en

98 See section 4.1.3 and https://www.ejp-eurad.eu/implementation/knowledge-management

99 For more details - https://publications.jrc.ec.europa.eu/repository/handle/JRC131993 and https://publications.jrc.ec.europa.eu/repository/handle/JRC136139

100 G. Pavel et al., Education, training and mobility, knowledge management: towards a common effort to ensure a future workforce in Europe and abroad, EPJ Nuclear Sci. Technol. 9, 21 (2023)

aiming at improving accessibility to Euratom funded research results for the European research community and improving synergies between direct and indirect actions.

Dissemination and exploitation of results - like in Horizon Europe, focus is put on beneficiaries' efforts and the responsibility of the project consortium in disseminating and exploiting results[101]. Projects are requested to identify and to declare ownership projects results in the reporting and to list their key exploitable results. Overall, Euratom co-funded European Partnerships (PIANOFORTE, EURAD, EUROfusion) performed generally well in disseminating results although there is still room for improvement in view of exploitation. To support beneficiaries' efforts, the Commission offers specific tools and services shared with Horizon Europe:

1. The **Horizon Results Platform**, set up in 2019, provides a space for beneficiaries to give their results visibility beyond the end of the project and to express their needs for further results uptake.
2. The **Horizon Results Booster** (2020-2024) and re-enforced **Horizon Results Booster-II**[102] (from late 2024) also provide free support and guidance services to beneficiaries for disseminating and/or exploiting their results.

Open access to publications and other research products allows researchers to build on existing work, industry to access scientific knowledge to innovate, and public sector to use for evidence-based policy making. Therefore open access supports indirectly objective of the Euratom Programme to create and share high quality new knowledge for improving nuclear safety, radiation protection, waste management and for development of fusion energy. The Commission integrated open access to scientific peer reviewed publications in the rules for Euratom Programme and promoted it with Member States and with stakeholders. For Euratom-funded research, the data103 shows open access to 76% of peer reviewed scientific publications from projects launched since 2021, an improvement compared to 66% publications from 2014-2020 projects.

4.1.7.3. Support for technology transfer from the research to industry

In support of technology transfer and the promotion of non-power applications of fusion research, EUROfusion implements the Technology Transfer Programme with Open Calls for Demonstrators since 2022 and executes together with F4E an European Fusion Technology Marketplace[104]. The Technology Transfer Programme provides funding

[101] As per the Article 39 of the Horizon Europe regulation (applicable to Euratom programme) , beneficiaries of the EU's research and innovation framework programmes are legally obliged to disseminate and exploit results. The beneficiaries are best placed in maximising the impact of their own research by communicating, disseminating, exploiting during the project's lifetime and after the project's completion.

[102] https://www.horizonresultsbooster.eu/

[103] Data retrieved from Scopus (December 2024)

[104] https://fusion-technology-transfer.europa.eu/

opportunities for recipients of EUROfusion-based technology or know-how, encouraging innovation and supporting feasibility studies for non-fusion applications. The entrepreneurs are assisted by the FUTTA III Consortium, a group of specialised brokers organised by an external consultancy (InExtenso Innovation Croissance) chosen by the EUROfusion consortium. The broker team covers Austria, Belgium, France, Germany, Greece, Italy, the Netherlands, Spain and Portugal. FUTTA is able to attract additional projects and showcase fusion applications in various sectors to SMEs, startups and universities[105]. Moreover, relevant industrial actors are engaged through EUROfusion grants for industry involvement (EUR 2,46 million in subcontracting and EUR 6,03 million in activities of the affiliated entities over 2021-2022).

4.1.7.4. Support for the preparation and development of a competitive European fusion industrial capacity

Commission actions focused on supporting involvement of European industry in fusion R&D and cofunding industry-driven innovation in nuclear fusion and fission in line with legislation in force (NZIA[106] and STEP[107]). For the former, a dedicated framework contract for the provision of industrial expertise to EUROfusion (EUR 10.14 million in 2020-2024) with 15 specific contracts was managed by the Commission to support EUROfusion in the conceptual design of DEMO and DONES. Services included provision of an industry best practice-based assessment of power plant system architecture, overall configuration and system engineering processes with a focus on design and technology options and feasibility, manufacturing options as well as risk identification, evaluation and mitigation. Collaboration with industry is also promoted through the Fusion Industry Innovation Forum (FIIF)[108], consisting of 16 members from the EU industry involved in the fusion sector.

Regarding support for an industry-driven innovation in nuclear fusion and fission, European Innovation Council provides funding[109] to accelerate and grow nuclear innovations via EIC support schemes. Euratom coordination and support action concerning the European Fusion Industry Platform is described in section 4.1.8.

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105 https://fusion-technology-transfer.europa.eu/success-stories/

106 Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724

107 Regulation (EU) 2024/795 of the European Parliament and of the Council of 29 February 2024 establishing the Strategic Technologies for Europe Platform (STEP), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202400795

108 https://www2.euro-fusion.org/fiif/

109 For details see https://eic.ec.europa.eu/eic-2025-work-programme_en

4.1.7.5. Support for the provision, availability and appropriate access of European and international research infrastructures, including JRC's infrastructures

Euratom support for access to research infrastructures is provided through the OFFERR project[110] (225 facilities) and through the Open Access programme of the JRC (11 labs over 3 sites)[111]. OFFERR project[112] (EUR 9 million of Euratom funding) set up a European User Facility Network (EUFN) and established an operational scheme facilitating access to nuclear science infrastructure. The financial support is granted to proposals jointly prepared and agreed by the visiting team and the user facility after an independent evaluation of proposals. The co-operation has been established with European Partnerships (PIANOFORTE, Connect-NM, EURAD), ENEN2plus and the JRC. Most of the facilities offered are in FR, DE, HU, CZ, PL, SK, ES and in the JRC research centres. OFFER's initial results after two years are positive – project awarded support to 31 teams and 24 research facilities. First data shows that the Member States most represented in projects granted access to EUFN include: FR, CZ, DE, BE, FI. Research fields covered include: LWR reactors (34% of total financial support), advance nuclear fuels (22%), waste & decommissioning (20%), advanced reactors (9%), nuclear science applications (8%) and innovation in nuclear instrumentation (4%).

In parallel, the JRC also provides open access to its nuclear infrastructures in Karlsruhe, Geel, Ispra and Petten[113], playing a vital role in stimulating research, sharing expertise, and enhancing skills. 11 nuclear facilities made accessible to researchers allow experimental research to assess structural materials for nuclear systems, to safely investigate the properties of actinide materials, including under extreme conditions, or to analyse the behaviour of nuclear spent fuel and radioactive waste. Through a joint pilot project between direct and indirect actions, financial support has been provided to external users and allowed 190 researchers from EU Member States and third countries associated to the Programme to access the facilities and perform experiments in its nuclear laboratories since 2021.

Assessment of Euratom actions for developing expertise and competences by experts and feedback from public consultation – independent experts favourably noted Euratom's long-term support for capacity building and for the access to nuclear research facilities in a form of two large projects ENEN2plus and OFFERR[114].

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110 https://cordis.europa.eu/project/id/101060008

111 For more details see https://joint-research-centre.ec.europa.eu/tools-and-laboratories/open-access-jrc-research-infrastructures_en#nuclear-laboratories

112 https://snetp.eu/offerr/

113 European Commission, Joint Research Centre, Jenet, A., Acosta-Iborra, B., Aldave de la Heras, L. et al., Open access to JRC research infrastructures, Publications Office, 2021

114 Liisa Heikinheimo, Stefano Monti, *Interim evaluation of indirect actions for nuclear safety under Euratom Research and Training Programme 2021-2025 and recommendations for 2026-2027 extension*, June 2024

Box 7 - Recommendations from independent experts

- **JRC** should enhance its education and training activities by **expanding cooperation with research institutions and universities of EU Member States**.
- Commission should consider **developing an infrastructure ecosystem inside the Euratom research activities**. The ecosystem should include co-operation with international projects and enable Euratom projects with different schedules to benefit fully of these infrastructures.
- As regards EHRO-N, the panel acknowledged the strengthened collaboration with European networks and organisations and enjoined the JRC to continue coordinating EU Member States efforts to collect information at state level to analyse human resources needs in the nuclear field.

Source: Heuer, R. et al., Interim evaluation of the activities of the Joint Research Centre (…) and *Liisa Heikinheimo, Stefano Monti, Interim evaluation(…)*

Similarly, experts also commended the JRC's education and training actions for its effectiveness and relevance, including the open access to the nuclear research infrastructure, which is essential to maintain high level of skills in the EU[115]. Experts' recommendations for improvements are shown in Box 7 and feedback from public consultation is provided in Box 8.

Box 8 - What messages emerged from public consultation?

1. **Education and training (E&T) matters are important for the Programme's stakeholders**. More than half of respondents (58%) said that they are engaged in E&T activities. This was also reflected in the **respondents' strong support for E&T actions in the Programme**: 50% strongly agreed and 33% agreed with the statement that the Programme's E&T priorities are relevant.
2. Respondents seem to generally **approve of the Programme's direction regarding E&T**. 36% said they agree and 26% said they strongly agree with the statement that the Programme was delivering in its objectives on E&T.
3. Respondents also noted the **relevance of JRC's actions in the area of nuclear knowledge and competences** (E&T, capacity building and open access to research infrastructure) to address current challenges of the nuclear field: 35.9% of respondents strongly agreed and 34.36% agreed with the statement.
4. When asked about specific Euratom E&T initiatives, 45% respondents said **ENEN2Plus increases impact** to a great extent and 27.69% said that it does this somewhat. 26.67% said they were satisfied and 20% said they were very satisfied with the support ENEN2Plus gives to E&T. Respondents were also **positive about the opening of post-doctoral fellowships under Marie Skłodowska-Curie Actions (MSCAs) to nuclear researchers**. 37% agreed that this opening increased the Programme's relevance and strengthened its impact "to a great extent" and 32% said it was "somewhat".
5. The **open access programme to the JRC's nuclear infrastructure** was underlined as one of three areas (out of 11) where the JRC brings the **most added value** to the Euratom programme, together with expertise in current and innovative nuclear technologies.

[115] Heuer, R., Florea, A.M., Herranz Soler, M., Janowski, T., Keskitalo, E.C.H., Maas, R., Oddou, J., Pálinkás, J. and Wegener, H., Interim evaluation of the activities of the Joint Research Centre under Horizon Europe and Euratom 2021-2025 - Final report of the evaluation panel, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/63710, JRC134811.

Commission services' views are similar to the experts' conclusions and recommendations. Euratom projects face risks of research reactors' availability and unexpected costs. For example, scheduling the irradiation campaigns is depending on the research reactor operations and requires long term planning that an individual project cannot provide. Euratom projects will need to develop closer links with infrastructure through expanded user facility network or Partnership for research in nuclear materials (CONNECT-NM). Similarly in training and mobility, individual projects could benefit from closer cooperation with ENEN2Plus.

4.1.8. Development of fusion energy

Outputs 2021-2023					
55%	**2051**	**6842**	**564**	**470**	**8**
of the fusion roadmap's milestones reached by EUROfusion	Peer review publications since 2021	Researchers supported to access fusion research facilities	PhD degrees in fusion sciences completed by students supported by EUROfusion	MSc degrees in fusion sciences completed by students supported by EUROfusion	Shared research facilities in Europe (tokamak, stellarators, supercomputers) jointly managed by EUROfusion

The Programme's cornerstone, the cofunded European Partnership EUROfusion has made a **substantial progress in terms of experimental campaigns, preparations of research facilities and research addressing 8 roadmap's missions[116] to develop fusion** (see box 9, see also Annex VI for a detailed overview). Different indicators show that EUROfusion delivers in terms of research milestones set in 2021, supporting mobility & access to research facilities and training of new generation of researchers and engineers. In 2023, it successfully achieved the research goals of the final deuterium-tritium experimental campaign at the Joint European Torus (JET) device. The experiments explored fusion processes and control techniques under conditions similar to and in preparation of future fusion power plants, directly supporting the preparatory phases for ITER's future experiments. The first fusion power plant is now in the concept design phase, which will entail the assessment of technical feasibility studies, addressing safety and licensing issues and evaluating life cycle costs. Although there is a strong continuity among most of the activities funded by the 2014-2020 and 2021-2025 Programmes, EUROfusion also launched reviews to make adjustment in some areas – the consortium carried out in 2023 human resources survey[117] and fusion facilities review.

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

117 The 2023 Human resources survey for the European Union fusion research programme, EUROfusion, April 2024, https://euro-fusion.org/wp-content/uploads/2024/05/EUROfusion_2023HumanResourceSurveyandDevelopmentReport.pdf

Box 9 - Scientific highlights from Euratom-funded research

1. In 2022, EUROfusion started **conceptual design** activities for the Europe's first demonstration fusion power plant to demonstrate the net production of 300 to 500 megawatts of clean and safe fusion energy to the grid[118].
2. In 2023, EUROfusion's **experimental campaign in JET** produced 69 megajoules of fusion energy using deuterium-tritium fuel while sustaining fusion during a six second pulse, improving upon its record from 2021[119].
3. In 2023 **construction started of IFMIF-DONES** in Granada, Spain, a research infrastructure for testing, validation and qualification of the materials to be used in future fusion power plants like DEMO. The engineering design and the safety report of IFMIF-DONES were completed by EUROfusion. The Programme provided in 2023 a grant for consolidation of preparations of this facility[120].
4. In 2024 EUROfusion started **experimental campaigns** in two important research facilities: **Wendelstein 7-X Stellarator** (Germany) and **JT-60A Tokamak** (Japan).

Source: European Commission

These achievements are substantial, however the EUROfusion actions must be assessed also in a broader context of evolution of fusion research landscape worldwide.

Among the different existing fusion technologies, **the tokamak-based fusion** is currently considered as the **most mature for attaining commercial production of electricity**. Tokamaks, defined by the doughnut shape of their inner chamber, are the most studied and best understood concept for 'magnetic confinement' fusion[121]. The EU is therefore leading **ITER**[122], a unique international collaborative research project, which objective is to **demonstrate the scientific and technological feasibility of tokamak-based fusion energy**. Its results will be fundamental in the design of a first fusion power plant that will produce electricity to be delivered to the grid in the second half of this century. This will pave the way to industrial development of fusion power plants and commercialisation of fusion power generation.

ITER has however been subject to a number of serious challenges in recent years. The ITER Organization is currently **re-examining the baseline of the project** in line with the initial objectives[123]. The aim is to achieve the fastest path to the start of the ITER plasma phase, during which the most significant experiments are planned, while minimizing the technical and licensing risks.

[118] For more details see https://euro-fusion.org/eurofusion-news/horizon-eurofusion-event-announces-start-of-conceptual-power-plant-design/

[119] For more details see https://euro-fusion.org/eurofusion-news/dte3record/

[120] For more details see https://ifmif-dones.es/ and https://euro-fusion.org/related/ifmif-dones/international-materials-facility-ifmif-dones-starts-construction-phase/

[121] https://euro-fusion.org/fusion/fusion-on-earth/

[122] https://www.iter.org/few-lines

[123] https://www.iter.org/node/20687/updated-baseline-presented

In parallel, the world is already in a **race to industrialise fusion technology**, even before achieving power generation. Several breakthroughs in fusion energy production have been recently announced[124] in the world, among them some promises for fast commercialisation of fusion-based power generation. Various start-ups around the world, in particular in the US, are making headlines and attracting investments for demonstration projects targeting a variety of concepts (from variants of the tokamak to radically alternative approaches) that should become operational over the next decade[125].

The EUROfusion has delivered well on its high-end scientific research mission in the 2021-2024 period. However, based on independent expertise[126], the Commission judges that EUROfusion is not fit to achieve commercial exploitation of fusion power generation (see Box 10).

Box 10 - Key findings on Euratom-funded fusion research from independent experts

- The current **EUROfusion roadmap**, based on the sequential development of JET-ITER-DEMO**, is considered overly complex and unrealistic from a timeline perspective.**
- The main concerns relate to the lack of testing and qualification of components under relevant fusion conditions and the means to address these issues.

The strategy for fusion research in the EU is currently set out in the EUROfusion roadmap, which was published in 2012 and updated in 2017. This roadmap, based on the sequential development and exploitation of JET, ITER and DEMO facilities, is considered overly complex with an unrealistic timeline. The main concern is that the ITER organisation is currently re-examining the project baseline, which may result in a 10-year delay to the first experiments and leave the industrial supply chain idle. The second concern is that EUROfusion does not sufficiently address some key enabling technologies, such as radiation resistant materials, breeding blankets and the tritium fuel cycle, plasma heating technologies and advanced magnet systems for improved plasma confinement. This concern is aggravated by the lack of specialised facilities for testing and the qualification of components in a relevant fusion environment. A further concern is that the costs of a first fusion power plant have not yet been quantified and are probably very high. Although EUROfusion is an impressive collaborative effort from the European laboratories, risks and uncertainties in their respective missions have not been fully assessed or quantified. Significant technological challenges remain, and it is currently unclear how much time and resources will be required to resolve the issues.

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124 National Ignition Facility in the United States made headlines in 2021-2023 by achieving a world first burning plasma state of 'ignition', in which the plasma is predominantly self-heated by the fusion reactions. Fusion records in temperatures and sustained plasmas have also been achieved by the KSTAR (Korea) and EAST (China) tokamaks.

125 European Commission: Directorate-General for Energy, *Foresight study on the worldwide developments in advancing fusion energy, including the small scale private initiatives*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2833/967945

126 European Commission, Summary report - Interim Evaluation of Euratom Fusion Programme 2021-2025 and Ex-ante Assessment of Extension of EURATOM Fusion Programme 2026-2027

The fusion landscape is changing fast, becoming more dynamic thanks to several private initiatives in Europe and worldwide. There is a significant risk that EUROfusion, as a co-funded public-public partnership, may fail to systematically include these dynamic developments. EU fusion engineering knowledge and industrial potential, developed over decades with significant public investment, might be lost and move to countries outside the EU with a more favourable economic and regulatory landscape.

It is important to acknowledge that difficult scientific and technological questions remain to be solved before fusion can be brought to the market. There is a growing consensus, notably captured at events[127] and in a public consultation organised by the Commission in 2024 (see Box 11), that Euratom's approach today to fusion development should move away from seeing ITER and other initiatives in a sequential way. There is deemed to be an urgent need to develop an EU strategy that provides the right conditions and proper framework to address the technological bottlenecks on the path to the commercial deployment of fusion energy.

Box 11 – Results of public consultation – respondents views on how to accelerate development of fusion energy in Europe:

1. The European Commission should **develop an EU Fusion Strategy** with a concrete short-term action plan and a comprehensive, long-term roadmap to advance fusion energy development and to establish the necessary ecosystem for the future commercialisation of fusion energy - 21% (42) of respondents agreed, 34% (67) strongly agreed, while 23% (45) did not know, 14% (27) were neutral, and 7% (14) disagreed or strongly disagreed.
2. The **industrial sectors and potential private investors' involvement is necessary** to accelerate the transition to commercial fusion energy - 28% (54) of respondents agreed, 34% (67) strongly agreed, while 21% (40) did not know, 10% (20) were neutral, and 7% (14) disagreed or strongly disagreed.
3. Resolving critical technological bottlenecks and demonstrating fusion technology to accelerate the development of enabling technologies will require a strong **partnership between the public and private sectors -** 27% (52) of respondents agreed, 32% (63) strongly agreed, while 22% (42) did not know, 14% (27) were neutral, and 6% (11) disagreed or strongly disagreed.

The EU must clearly define the programmatic priorities, including a clear identification of the major remaining knowledge gaps. Building a more realistic EU fusion R&D programme with a reasonable time frame and based on acceptable cost will substantially mitigate failure risks. This programme must be milestone-driven and has a strong project culture. It will need to tackle the technology bottlenecks which require additional focus and investment while involving more private financing, industry experience and increasing the international collaboration with reliable partners where there is a clear added value for the EU. Development of such programme requires also rethinking the role, activities and budget of the EUROfusion Partnership.

The Commission made first steps in this direction by launching in May 2024 a call for launching a European Fusion Industry Platform and for preparation for a Public-Private

[127] High-Level Roundtable on Fostering Innovation for Fusion Energy in Europe (14 March 2024) and 'The EU Blueprint for Fusion Energy' meeting (23 April 2024)

Partnership on Fusion Energy[128]. This action is expected to start its implementation in early 2025 and plans to open the way to a future Public-Private Partnership (PPP). It has been forecasted to encourage scientific development and combine efforts from both private and public actor. It will also engage private investors of this emerging sector who aim to enter the field of nuclear fusion, and it will increase the fusion technological maturity, moving from a purely academic to a more industrial view. In particular, it will establish an industry-led European Fusion Industry Platform in view of a possible evolution into a long-term European Technology and Innovation Platform, a European fusion industry association for signing the PPP Memorandum of Understanding (MoU) and define a Strategic Research and Innovation Agenda (SRIA) on Fusion Energy. It would support the creation of a PPP during the 2026-2027 Euratom programme extension, which will align with the commission's goal of enlarging the EU fusion industry to tackle the critical bottlenecks and supporting innovation in the development of key enabling technologies, including alternative fusion concepts.

4.1.9. International cooperation

The Euratom Programme is **open to the participation of countries having concluded association agreements**, and is also open, at the project level and on the basis of mutual benefit and subject to acceptance by the consortium, to the participation of entities from third countries and of international organisations for scientific cooperation.

76% of Euratom-funded fission projects launched during 2021-2024 **involve participants from associated and 3rd countries[129]**. The projects signed in the first four years of the Programme involve around 36 participations from Ukraine (only country associated to the Programme) and 126 participations from third countries: Canada, China, USA, Japan, South Korea, South Africa, Türkiye, Norway Switzerland and the UK. While Ukrainian participants received funding under the same conditions as beneficiaries from EU Member States, financial support for non-association third countries is very low (EUR 560 000 in total), their participation being limited to cases where their participating entities were considered, by independent experts, essential for the implementation of project, mainly in nuclear materials (UK), tritium management (UK), accident tolerant fuel (Japan and USA), nuclear data (Switzerland).

Associations to the Programme: the Euratom Research and Training Programme is open to the association of third countries with advanced nuclear research programmes meeting the requirements set out in the Regulation establishing the Euratom Programme[130].

[128] Call topic HORIZON-EURATOM-2024-NRT-01-01 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-euratom-2024-nrt-01-01

[129] Data from signed grants agreements

[130] Article 5 of Council Regulation (Euratom) 2021/765

Association is the closest form of international cooperation as these countries can participate under the same conditions as EU Member States.

An **Association agreement of Ukraine to Euratom Programme**[131] which entered into force in 2022, allows for equal Ukraine's participation in all parts of the Euratom programme and provides for reduced Ukrainian financial contribution to the Programme. Cooperation in fission research with Ukraine is vital for sharing EU research excellence and the EU's nuclear safety culture with the Ukrainian nuclear sector. Ukraine's association to the Euratom Programme gives European researchers access to Ukraine's experience in operation and servicing of Nuclear Power Plants based on designs (VVER) common in Eastern and Central Europe. Ukrainian research institutes and companies participate in one-third of all projects launched in 2021-2025 (19 projects compared to 18 in 2014-2020 Programme). Ukraine participates in two Euratom co-funded Partnerships: EURAD-2 and EUROfusion. Ukrainian beneficiaries should receive about EUR 7.4 million from 2021-2025 Programme.

Situation concerning the United Kingdom: in 2023 the UK decided to not associate to the Euratom Research and Training Programme 2021-2025. However, data for the 2021-2025 Programme show a strong interest of UK participants to be involved, at their own cost, in Euratom fission projects (41% of all projects) and in fusion research. UK partner, UKAEA is associated partner to EUROfusion that participates in 18 (of 28) research work packages. Besides JET, UKAEA's contribution to the EUROfusion work is mostly based on the use (or future use) of three research facilities (HIVE, CHIMERA, H3AT). UKAEA estimated budget involvement in the action amounts to EUR 300 million, about 30% of total EUROfusion costs. In this regard, the UKAEA plays a significant scientific and financial role in the EUROfusion. Therefore, despite the fact that the UK decided not to associate to the current Euratom Programme and to focus on funding domestic fusion development, the Commission decided to accept EUROfusion's position, according to which they should keep the UKAEA as associated partner with reduced participation in the governance. This cooperation will be reassessed in view of the extension of the EUROfusion grant for 2026-2027, subject to Council decision on the Euratom Programme, taking into consideration the EU's strategic needs and contractual requirements.

Situation concerning Switzerland: The Commission and the Swiss Government have concluded in December 2024 negotiations on the association of Switzerland to Horizon Europe and the Euratom research and training programme. The signing of the Agreement is expected to take place in 2025, pending the completion of all necessary validations on both sides[132]. Until 2024, Swiss entities could not become full beneficiaries of Euratom

131 https://eur-lex.europa.eu/EN/legal-content/summary/association-agreement-on-ukraine-s-participation-in-the-horizon-europe-programme-and-the-euratom-research-and-training-programme.html

132 https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/eu-and-switzerland-successfully-conclude-negotiations-horizon-europe-and-euratom-2024-12-20_en

Programme, but they participate as third parties in 21 projects without funding (as associated partners), including European Partnerships EURAD-2 and EUROfusion.

4.2. Efficiency

This section reports the actual costs of the Euratom Programme's indirect actions and presents an assessment of the JRC resources and organisation. It also assesses how simplification measures performed relative to targets and objectives. This evaluation is based on findings of the interim evaluation of Horizon Europe[133], as the Euratom Programme was implemented using Horizon Europe's instruments and rules of participation[134].

4.2.1.1. Costs and benefits of Euratom Programme

Implementing the Programme gave rise to several types of costs incurred by different stakeholder groups. The operational expenditure of the Programme is EUR 852 million[135]. It is funded through the Union's budget and allocated to research and innovation projects. At the end of December 2024, EUR 671 million have been committed and EUR 527 million have been allocated for payments to beneficiaries.

The Euratom administrative expenditure budget of EUR 537 million[136] is the administrative cost of the European Public Sector (JRC and RTD) supporting the programme and funded through the budget of the EU. At the end of December 2024, about EUR 429 million have been committed and EUR 408 million paid out.

Beneficiaries incur administrative costs to fulfil specific requirements, set out in their grant agreement, which they would otherwise not have spent to manage their projects. While beneficiaries are compensated for all administrative costs through grant payments, any avoidable part of the effort induced by the programme's requirements reduces its overall efficiency. The HE interim evaluation collected a robust quantitative evidence base on beneficiaries' administrative costs as share of their total project costs, which will applied to calculations concerning Euratom Programme[137]. These costs likely cover tasks that would in any case have been associated with the running of the projects and only set an upper bound of what can be interpreted as "administrative burden". The median and the most frequent responses indicated that 6% to 10% of the project budget is allocated to administrative tasks.

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133 Commission Staff Working Document (forthcoming) on interim evaluation of Horizon Europe

134 Article 7(1) of Council regulation (Euratom) 2021/765

135 The operational budget for programme's direct and indirect actions, see also section 2 on the programme's implementation

136 Administrative budget for 2021-2025, including EUR 491 million for direct actions (JRC) and EUR 46 million for indirect actions implented by DG RTD

137 For details, see Annex 4.1.1. to SWD on interim evaluation of HE.

Consequently, for all projects signed under Euratom Programme so far over their entire project lifetime, beneficiaries are expected to spend between EUR 122 million and EUR 163 million in administrative costs, equivalent to 9% - 12 % of the total project cost[138]. The estimate of the total is an order of magnitude higher than that of the final Euratom Programme 2014-2020 evaluation (EUR 12 million to EUR 20 million[139]) over the entire duration of the programme). The differences are likely driven by a change in survey question design and improvements in data quality, rather than actual underlying changes in beneficiaries' administrative costs.

While the costs associated with the Euratom Programme are incurred early on, its benefits only emerge over an extended 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 as presented in section 4.1. of this report.

4.2.2. Administrative efficiency of Programme implementation

Two types of quantitative performance targets set out expectations about the **administrative efficiency of the European public sector administering Euratom Programme's indirect actions**: the administrative time performance targets and the percentage share of administrative expenditure overall.

Regarding administrative time performance targets, different time targets were set for specific administrative processes[140], particularly the time-to-grant target (8 months – 243 days). The Average Time-to-grant (TTG) is 230 days for Euratom Programme, an improvement over the 2014-2020 Euratom Programme (238 days) and the 2007-2013 Programme (313 days). The Programme performs well on other metrics like Time-to-inform (TTI = 130 days, target is 150) and Time-to-sign (TTS = 97 days, target is 92 days).

The Euratom Regulation set out an overall **efficiency benchmark for the programme's administrative expenditure** for indirect actions of no more than **6%** of the budget envelope for 2021-2025[141]. The Programme's administrative expenditure implementation suggests that the Programme performed well against these benchmarks: the **average for 2021-2024 was 5.4%**.

JRC resources and organisation - for the period 2021-2025, the contribution to the direct actions under the Euratom programme is EUR 532 million, amounting to 38,5% of the

138 Calculation on the basis of methodology, see Annex 4.1.1. to SWD on interim evaluation of HE

139 See SWD(2024)271 on ex-post evaluation of Euratom Programme 2014-2020

140 See Article 31(1) of 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

141 Article 4(3) of Council Regulation (Euratom) 2021/765.

Programme and 27% of the overall JRC budget. The budget is distributed across three main categories: staff expenses for permanent and non-permanent personal (63,1%); means of execution for maintenance of building and equipment (29,1%) and operational expenses for scientific work (7,8 %). The JRC generates revenues through financial agreements with other Commission services or contract work for third parties such as industry or regional authorities. Compared to 2014-2020 Programme, the JRC does not benefit in the current Programme from grants funded by indirect actions. It participates in the projects as a beneficiary requesting zero funding. It bears the operational costs for its own staff and research infrastructure via its institutional budget.

Similarly to indirect actions, the **budget for direct actions under the Euratom programme 2021-2025 has been reduced by 19.7% compared to 2014-2020, when considering a 2% nominal inflation**. The budget cuts have caused staff reduction for the JRC of 129 FTE, proportional to the direct action's budget cut in constant prices. These reductions are to be spread over the 7 years of the financing period and aim to reduce 96 permanent posts (2021-2027) and 33 temporary ones (2026-2027). There is also a significant overhead component associated to the infrastructure management of the JRC sites covering nuclear research. As a result, the JRC has adopted efficiency measures. These are reflected in the **new strategy for its nuclear activities and the management of its infrastructures adopted in 2022**[142]. The new nuclear strategy plans to align as much as possible the available resources in the priority research areas with the Programme's budget cuts.

The JRC strategy has defined **5 key areas of action for a reduction, realignment and focusing of activities while maintaining core added value and capacities** in high priority areas, in order to keep supporting a safe and secure use of nuclear and radioactive technologies in the EU and anticipate future needs and challenges. This was also a recommendation stemming from the ex-post evaluation of the Euratom programme 2014-2020[143] to develop and apply criteria in relation to JRC unique strengths and policy relevance for deciding to prioritise or not an activity.

Concerning the nuclear activities, the strategy plans a prioritisation and rationalisation of projects along screening criteria based on legal obligation, relevance and impact while enhancing more integrated collaboration with non-nuclear domains within the JRC.

In relation to the JRC's infrastructures, the aim is to eventually **concentrate and cluster the nuclear experimental facilities with nuclear materials (hot laboratories) across two sites, JRC-Geel and JRC-Karlsruhe**, while the site of JRC-Petten shall remain relevant with sufficient competent resources to staff laboratories that do not experiment

[142] Goulart De Medeiros, M., Wastin, F., Martin Ramos, M., Lanzke, G. and Geremicca, J., Executive Summary: JRC Strategy for its Nuclear Activities, Publications Office of the European Union, Luxembourg, 2023 https://publications.jrc.ec.europa.eu/repository/handle/JRC132060

[143] Ex-post evaluation of direct actions of the Euratom Research and Training programmes 2014-2018 and 2019-2020, COM(2024) 549

with radioactive material. Currently, the JRC's nuclear facilities are operational in Geel, Petten, Karlsruhe and Ispra and are subject to compliance with strict national requirements and monitoring by the respective national nuclear authorities. To reduce administrative burdens and pressure on the budget, efforts will also be made to identify synergies and efficiencies and improve interoperability across the four sites. This internal optimisation process is accompanied by an effort to enhance the shared use of facilities with Member State partner organisations and Commission stakeholders.

Since the beginning of 2021-2025 Programme, the JRC has been going through a transformational process that included a new organisation of its research structure. **A new way of working with portfolios** has created the foundation for a more agile approach towards programming the JRC's work, responding to priorities while improving efficiency and facilitating the integration of work across domains. Portfolios are helping the JRC to strike a better balance between the different areas of specialisation and the integration required to best serve policy needs. **Three nuclear portfolios concentrate core activities related to nuclear safety, including innovative technologies like SMR, nuclear safeguards and the policy support** in relation to compliance with the regulatory framework. JRC's work programme also includes so-called mixed portfolios in the area of health (non-power applications for medical purposes), in the area of security and situational awareness (nuclear security and dual-use expertise), in the area of international cooperation (support to the INSC) and across various portfolios (knowledge management and foresight in the nuclear field).

4.2.3. Simplification measures for Euratom Programme 2021-2025

As Euratom Programme relies on the Horizon Europe's rules and instruments, simplification of the Programme's implementation is linked to measures undertaken for the Framework Programme[144]. Optimising the FP's delivery has been one of HE's specific objectives[145].

One of the main simplification measures for Euratom is implementation of a large part of the Programme through four co-funded European Partnerships (76% of budget for indirect actions, EUR 619 million), with reduction of number of collaborative projects (58 projects in 2021-2025 compared to 67 in 2014-2018). This allowed 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. This paradigm shift promoted much greater ownership of the research fields for the beneficiaries. At the same time, it created more demanding project management responsibilities for beneficiaries than a classic collaborative project.

144 This section draws on conclusions of the section 4.2 of SWD for HE interim evaluation (forthcoming)

145 See recital (58) of 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

Commission introduced simplified cost options, in particular optional unit costs for personnel (in May 2024), bringing further simplification and helping to reduce errors. Other measures, such as a single, simpler corporate approach for charging personnel costs and the shift of Horizon Europe's control strategy towards identifying and addressing high-risk areas, should reduce irregularities and facilitate the work of beneficiaries. Possible further HE simplification measures to facilitate implementation of the co-funded partnerships will have substantial impact on Euratom programme.

Feedback collected from stakeholders suggest there has been **no substantial shift in the proposal preparation effort required to apply for funding and participate** in 2021-2025 Programme compared to 2014-2020 Programme (see Box 12).

Box 12 – Public consultation – respondents views on effort needed to participate in the Euratom Programme 2021-2025 compared to its predecessors with regard to:

4. **Time**: 49% (95) - similar; 13% (26) - greater; 10% (20) - lower; 28% (54) - don't know/no opinion;
5. **Resources:** 50% (98) - similar; 15% (30) - greater; 7% (13) - lower; 28% (54) - don't know/no opinion;

Application stage and proposal evaluation process - Horizon Europe applicants responding to open questions of the targeted survey provided a small number of specific suggestions for simplification of the **application stage,** evolving around the topics: User-friendliness, finding the right call, IT tool for submission, application template, additional requirements of horizontal topics[146]. **Evaluators and the evaluation process** were the **main focus of concern** in the contributions to **open questions** of the targeted survey. Topics of concern included: quality of expert evaluators, level of detail of evaluation report, inconsistent scores for improved resubmitted proposal in a part of the programme, technical glitches in online interviews. Structured qualitative responses to survey questions on the evaluation process hint at an **overall appreciation** of the process and the quality of the evaluation.

The **project implementation phase** remains an area of focus for **HE simplification measures** (and consequently for Euratom), which reduce beneficiaries' costs without negatively affecting the projects' R&I impact. Beneficiaries responded to open questions of the targeted survey and provided **specific feedback or suggestions** on related topics. Specific suggestions were received, including on: single personnel rate for SMEs, timesheets, helpdesk for administrative procedures and the on-boarding of new grantees[147].

4.2.4. Coherence

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: scientific support for

[146] For details see Annex 4.3.4. of SWD for HE interim evaluation (forthcoming)
[147] See Annex 4.3.4. of SWD for HE interim evaluation (forthcoming).

licensing of advanced fission and fusion systems[148], tritium management[149], and development of radiation-resistant materials[150].

Synergies between Euratom direct and indirect actions - the Council regulation introduced a single set of four specific objectives for direct and indirect actions. The aim is to simplify the Programme's implementation and to focus direct and indirect actions on the same objectives. It should also strengthen synergies and facilitate access of research consortia to the JRC's infrastructure and know-how. Coordination between direct and direct actions is ensured at programming level by co-drafting of respective work programmes and at operational level by coordination between RTD and JRC. The most important integration of RTD and JRC actions happens on the ground when JRC institutes participate in consortia funded by RTD by providing, without charge, expertise and access to nuclear infrastructures. The JRC funds its activities in collaborative projects from its institutional budget. For fission projects launched in 2021-2024, JRC institutes participate in 27 project consortia (52%). This is a significant increase compared to 2014-2020 Programme, where JRC participated in 40% of projects.

Further synergy is explored between direct and indirect actions with the set-up of pilot projects, like on open access to JRC's nuclear facilities, where new collaboration methods are tested in the area of knowledge and infrastructure management. This pilot project to fund European researchers' access to the nuclear infrastructures was launched in 2020 and has been extended in 2023 until 2025.

The overall assessment of RTD - JRC coordination is overall good but faces some shortcomings reflected in the differences between direct actions (aiming at performing research) and indirect actions (aiming at funding collaborative research). This results in different approaches in the implementation and governance of the programme, as funding the indirect actions require an appropriate management of the administrative budget, whereas the direct actions require managing research activities directly. As per the governance, the JRC has a single Board of Governors covering all (EU Research Framework Programme and Euratom Programme) activities, while the indirect actions have a dedicated fission configuration 'comitology' committee for the Euratom Programme.

Synergies with ITER - fusion research carried by EUROfusion Partnership is cofunded through the Euratom Programme, while the Joint Undertaking Fusion for Energy (F4E) is focused on delivering the European contribution to ITER's construction in Cadarache, France. Additionally, F4E is leading Euratom activities within the Broader Approach[151]. Research support for ITER construction and future operation is an integral part of EUROfusion's work. Cross-cutting nature of EUROfusion and F4E activities underlines

148 Project HARMONISE https://cordis.europa.eu/project/id/101061643
149 Project TITANS https://cordis.europa.eu/project/id/101059408
150 Project INNUMAT https://cordis.europa.eu/project/id/101061241
151 https://fusionforenergy.europa.eu/other-projects/

the need for a strategic discussion between Commission, EUROfusion, F4E and the Member States to cover all strategic issues related to the fusion development and delivery of electricity by a first fusion power plant. In 2024 RTD and ENER launched the Fusion Expert Group (FEG), an ad-hoc Commission Expert Group, bringing together Member States and stakeholders to provide advice on strategic fusion issues.

Synergies with Horizon Europe - basic acts establishing the Euratom Programme and Horizon Europe[152] introduced provisions promoting synergies with focus on education and training actions and on joint research for cross-cutting aspects of the safe and secure use of non-power applications of ionising radiation in sectors such as medicine, industry, agriculture, space, climate change, security and emergency preparedness and contribution of nuclear science.

During 2021-2024, the Commission succeeded in the implementation of limited synergies such as use of MSCA post-doc fellowships for nuclear researchers with Euratom funding or use of EIC funding[153] for fusion energy research via various support schemes.

Until 2024, 12 fellowships were awarded for a total Euratom contribution of EUR 2.2 million. The inclusion of synergies for non-power applications aimed to address issues like cancer treatment, medical radioisotopes, critical materials and space, relevant to Commission initiatives like the Beating Cancer Plan and the action plan on critical raw materials. However, due to the lack of specific implementing provisions including systematic screening for synergies via a permanent governance structure, or different budget level of HE and Euratom Programmes, more ambitious synergies such as complementary funding of joint calls for medical or other non-power applications of ionising radiation or funding of MSCA PhD networks were not implemented, and at this moment this area of synergies is underexploited. As shown in section 4.1.4, Euratom calls for proposals in 2021 and 2023 showed potential for innovative applications of ionising radiation applications. This potential could be further realised in synergy with actions funded under Horizon Europe as indicated by recommendations from STC and independent experts.

Regarding **coherence of the Euratom programme with EU 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 radioactive waste management and basic safety standards (BSS). As underlined by thematic evaluations, Partnerships such as EURAD-2 and Pianoforte play 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 address this point. In the case of radioactive waste management, the Member States have to

[152] Article 10 of Council Regulation (Euratom) 2021/765 and Annex IV to HE Regulation.
[153] For details see https://eic.ec.europa.eu/eic-2025-work-programme_en

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-2 supports 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 (see section 4.1.3).

4.3. EU added value

The actions funded by the Programme **help Member States to work together to develop nuclear technologies**, regardless of their national choice as to whether to generate or consume nuclear power. Euratom-funded research is of added value for all Member States as it concerns a **broad spectrum of applications of ionising radiation and risks, not only electricity production**. It enables Member States to harness the opportunities offered by the technologies in the interest of all citizens, while reducing the risks associated with ionising radiation.

The Programme significantly **increased the EU's ability to mobilise a wider pool of excellence, expertise and multidisciplinary in nuclear research**, achieving impacts that extend far beyond what would have been achieved at national or regional level. This is of particular benefit to smaller Member States, which were able to take advantage of economies of scale afforded by the Europe-wide pooling effect and open access to JRC facilities.

- More than **7200 researchers participated in joint exploitation of nuclear research facilities** in the EU[154]
- Programme enabled **access to about 244 research facilities**[155] across EU and in 3rd countries.

The Euratom-funded projects and JRC provide a **supportive framework for developing new generation of researchers**, sharing and maintaining expertise and skills in nuclear safety and security, the safe management of radioactive waste and radiation protection.

- **986 PhD students** in nuclear research benefitted from Euratom financial support and access to critical mass of researchers and scientific equipment[156].
- **962 students benefitted from Euratom mobility support**[157]
- **3324 persons provided with specialised nuclear training by JRC**

[154] Researchers who participated in experimental campaigns managed by EUROfusion, OFFERR and JRC
[155] Facilities offered through OFFER, JRC Open Access and EUROfusion.
[156] Supported by EUROfusion, PIANOFORTE Partnership and Euratom collaborative projects.
[157] Supported by ENEN2Plus and Pianoforte Partnership

Structuring effect of the Euratom co-funded European partnerships - European Partnerships in fission[158] and fusion research[159] deliver European added value through the development of long-lasting knowledge networks. All Partnerships have a strategic research agenda or work programme which brings together the EU and other partners such as Member States, industries and foundations, in agreeing on joint priorities for funding. This is a key feature that distinguishes partnerships from other collaborative projects[160]. Euratom Partnerships provide national laboratories opportunities to specialise in some key areas, make meaningful contribution, and maintain visibility within the European consortium. Partnerships also excel in providing opportunities for sharing of knowledge and best practices. For example, EURAD-2, partnership for radioactive waste management, provides knowledge for Member States with small inventories of radioactive waste (e.g. from hospitals and industry). These Member States face particular challenges concerning access to sufficient expertise in developing disposal options.

Data also show that the 2021-2025 Euratom programme's grants (EUR 812 million) lead to a **significant mobilisation of public and private funding from beneficiaries** – about EUR 547 million. This is equivalent to a **leverage factor of 0.401**: in other words, each euro the EU is investing in Euratom R&I projects directly attracts additional R&I investments for about 40 cents. In principle, due to their design and size (76% of all Euratom grants), co-funded partnerships leveraged the most (45 cents for each Euro invested)) compared to collaborative projects (Research and Innovation Actions, Innovation Actions, Coordination and Support Actions) which leveraged about 21 cents for each Euro invested by Euratom.

One of the key aspects of added value of Euratom Programme relates to its **ability to promote cooperation on a large scale across countries**. Most national (or regional) programmes may fund bilateral or, more rarely, trilateral collaborations, but usually they do not fund wider collaboration networks[161]. Of the EUR 812 million signed Euratom grants by December 2024, 99% are collaborative grants and Partnerships. **Collaborative grants involve an average of 16 participants**, On the other hand, three co-funded European Partnerships in fission research, involve on average about 81 participants each.

The added value of collaboration is reflected in feedback from public consultation (see Box 13).

Box 13 – Results of public consultation - what are the main benefits of participating in the Euratom Programme 2021-2025 compared to national or regional R&I programmes? ***[respondents could indicate more than one answer]***

1. 79% of respondents **- improved cooperation with partners from other countries** (within the EU and beyond)

158 https://pianoforte-partnership.eu/ , https://www.ejp-eurad.eu/ , https://www.connect-nm.eu/

159 https://euro-fusion.org/

160 Biennial Monitoring Report on European Partnerships, 2024, p. 19, https://data.europa.eu/doi/10.2777/991766.

161 European Commission (2024). Align, act, accelerate, p. 20, https://op.europa.eu/s/z14n

2. 36% of respondents - **improved international visibility**
3. 35% of respondents - **possibility to finance projects** which otherwise wouldn't have been supported at the national or regional level
4. 27% - respondents - **improved excellence in nuclear R&I** (e.g. more high impact publications and patents)

The EU added value of the JRC's nuclear activities lays in the provision of robust scientific and technical expertise to the Commission's services and EU Member States, strongly contributing to the safe and secure use of nuclear technology. The specificity of the JRC's scientific advice and support to EU policy is tied with its scientific excellence and independence from national, private and other external interests. Moreover, the high quality of the scientific contributions is based on multi-disciplinary in-house competences in nuclear safety, safeguards and non-proliferation, strategic trade control, nuclear data and non-energy applications of nuclear technologies and on its often unique research infrastructure at EU level.

One particular asset of the JRC's capabilities include facilities and tools for the experimental characterisation of highly radioactive compounds, including irradiated nuclear fuel and other substances used in nuclear technologies. Thanks to state-of-the-art infrastructures, essential research can be performed on the safety of the nuclear fuel cycle, including for extended storage and disposal or for accident prevention and the characterisation of nuclear waste. Moreover, the JRC's facilities are made available to Member States' organisations for joint activities and through the JRC's Open Access programme, contributing to deliver and stimulate high-quality research. This is an undeniable asset for the Euratom community, which grants researchers use of installations they could not otherwise access to perform experiments. Overall, partnerships and collaborative schemes ensure full complementarity of research activities carried out by the JRC with national research programmes of EU Member States.

JRC's research on radiation in the environment supports national public health agencies with data and models to assess and manage radiation risks. In addition, the operation and maintenance of both EURDEP and ECURIE, complements national monitoring networks and provides a comprehensive picture of radiological conditions across Europe. The REMdb online platform developed by the JRC also answers a need to perform mandatory activities under EU legislation related to environmental monitoring. This supports work on emergency preparedness and response to radiological incidents, where the JRC aims to integrate nuclear competences in the broader European disaster response coordination, especially in view of the current geopolitical situation.

The JRC also conducts research that supports the development of new and innovative nuclear technologies in the non-power fields, which can enhance the competitiveness of European industry. As this area is gaining more traction at EU level with far-reaching societal impact, in particular on nuclear medical applications, the JRC's research justifies the investment in resources.

The education and training activities proposed by the JRC are a valuable complement to national efforts to maintain necessary nuclear skills and competences. The JRC is able to deploy and adapt its training offer in line with the needs of EU policymakers and Member States to respond to changing societal challenges. The provision of training and education under the Euratom programme is a clear EU added value for beneficiary Member States.

Research in nuclear security and nuclear forensics and the provision of trainings assist national law enforcement and security agencies and foster capacity-building in the event of illicit trafficking of nuclear materials, thus contributing to strengthen the Security Union. The technologies and methodologies developed by the JRC for nuclear safeguards also complement national efforts with tools that Member States can use to meet their obligations under international treaties and EU regulation. This is especially beneficial for countries with smaller nuclear programmes and without extensive expertise nor educational infrastructure in the nuclear field.

Research results obtained from the JRC's own research and through the funded consortia under indirect actions are also freely shared among Member States, ensuring a community of practice and knowledge.

4.4. Relevance of Euratom Programme

With the accelerating development and expanding use of nuclear technologies worldwide[162], the **Euratom programme provides the knowledge and solutions needed to benefit from these advancements, and to address societal concerns about radiation risks**. A number of challenges in nuclear security and safety, emergency preparedness, strategic energy autonomy has also been identified and addressed, as well as more generally a need to support the sustainability of EU nuclear skills for all future needs.

4.4.1. Responding to the needs of society

The focus of the fission part of 2021-2025 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. These areas constitute major responsibilities for Member States, operators and waste produces, with Euratom directives setting obligations[163].

The Euratom Programme is able to provide solutions based on research shaped according to the needs of beneficiaries. In particular, the Euratom co-funded Partnerships show the

[162] See reports from IEA https://www.iea.org/reports/the-path-to-a-new-era-for-nuclear-energy and IAEA https://www.iaea.org/newscenter/news/a-turning-point-first-ever-nuclear-energy-summit-concludes-in-brussels

[163] Waste management - https://energy.ec.europa.eu/topics/nuclear-energy/radioactive-waste-and-spent-fuel_en
Nuclear safety - https://energy.ec.europa.eu/topics/nuclear-energy/nuclear-safety_en

advantages of developing research actions with Member States and stakeholders. Based on joint programming[164], these collaborations result in research better aligned with their specific needs.

In the area of nuclear safety, less prescriptive call topics[165] allowed research stakeholders to propose projects addressing most relevant issues in safety, covering safety assessment methods, including ageing of materials for a long-term operation, as well as modelling under severe accident conditions (see section 4.1.2). Such research is relevant for maintaining safe operation of the current fleet of nuclear power plants responsible for 23% of electricity generated in EU in 2023[166].

Assessment of thematic areas of the Programme (see sections 4.1 to 4.1.8) confirmed the relevance of the current Euratom actions in their fields. The JRC's scientific and technical expertise provided to the Commission and Member States, as well as the use of specialised tools and facilities, help to strengthen the safe and secure use of nuclear technologies.

Results of the public consultation show that stakeholders consider changes introduced by 2021-2025 Programme as increasing relevance and strengthening the impact of the Programme (see Box 14).

Box 14 –What messages emerged from public consultation on Programme's relevance?

1. **Introduction of co-funded European Partnerships** contributed to an increased relevance and strengthening of the impact of the Euratom Programme: 29% (57) - to great extent; 34% (67) – somewhat; 5% (10) not at all; 5% (10) – a little; 2.5% (5) doesn't make a difference; 24% (46) don't know.
2. **Launch of the European platform promoting transnational access to nuclear research facilities** (OFFERR project) contributed to an increased relevance and strengthening of the impact of the Euratom Programme: 37% (73) - to great extent; 25% (48) – somewhat; 3% (6) not at all; 3.5% (7) – a little; 7% (13) doesn't make a difference; 25% (48) don't know.
3. **Support for mobility, education and training through a platform established by the European Nuclear Education Network** (ENEN2Plus project): 46% (89) - to great extent; 28% (54) – somewhat; 0.5% (1) not at all; 4% (8) – a little; 4.5% (9) doesn't make a difference; 17% (34) don't know.

[164] Joint programming produced common research agendas and roadmaps – for radioactive waste management https://www.ejp-eurad.eu/roadmap; for radiation protection https://pianoforte-partnership.eu/workpackages/wp2-research-and-innovation-projects/; for nuclear materials https://www.connect-nm.eu/orient-nm-documents/ ; for fusion energy https://euro-fusion.org/eurofusion/roadmap/

[165] See for example call topics HORIZON-EURATOM-2023-NRT-01-01 to 06 in Work Programme 2023-2025 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2023-2025/wp_euratom-2023-2025_en.pdf

[166] https://ember-energy.org/app/uploads/2024/10/European-Electricity-Review-2024.pdf

4.4.2. Response to emergencies and changing priorities

Euratom actions launched since 2021 clearly demonstrate the Programme's agility and flexibility. In response to the war in Ukraine, an amendment of the 2021-2022 call allowed to launch an ad-hoc call for a safe alternative fuel for VVER reactors and to address the issue of **security of supply of fuel for 35 Russian-designed VVER reactors operating in the EU and Ukraine**. Two EUR 10 million projects were selected, the first co-funded with a consortium led by Westinghouse[167]; the second, co-funded with a consortium led by Framatome[168]. This was possible thanks to the transfer of unspent ITER funds on the based on a separate amendment to the work programme. Other measures introduced in 2022 included that entities established in Ukraine were made eligible for funding under the Programme as the association agreement was delayed due to war[169]. Additional funding was provided to support resources, equipment and hardware of Ukrainian beneficiary and associated entities in fusion energy research.

The Programme also addressed emerging issues such as EU strategic autonomy and growing interest in SMRs[170]. The 2023-2025 call led to the selection of projects for maintaining this **autonomy in the development of nuclear materials development[171] and for nuclear data[172]** and computer simulation tools for all nuclear applications. Other actions support the **strategic autonomy in the supply of medical radioisotopes[173]** and in the field of **radioisotope power sources for space exploration[174]**. While the Council regulation provides flexibility in terms of implementation modes and instruments, the main limiting factor is the reduced budget, aggravated by the lack of third- party income.

4.4.3. Critical role of JRC

The demand for JRC's nuclear activities on security, safety and safeguards has been increasing during 2021-2024 indicating a critical role for the JRC's direct actions. The JRC retains the **relevant expertise to perform assessments of current and advanced technologies**, for example - analysis of SMR designs in terms of safety, safeguards and proliferation resistance can better inform Member States and the European Commission prior to full technology deployment in the EU.

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167 Project APIS https://cordis.europa.eu/project/id/101114673
168 Project SAVE https://cordis.europa.eu/project/id/101114771
169 See section on 'Actions for Ukraine'Euratom Work Programme 2021-2022 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/euratom/wp-call/2021-2022/wp_euratom-2021-2022_en.pdf
170 5 projects funded on different aspects of safety and licencing of light water Small Modular Reactors (total value of grants: EUR 26.9 million), facilitating SMR development and deployment
171 Launch of co-funded European Partnership for development of nuclear materials
172 Project APRENDE https://cordis.europa.eu/project/id/101164596
173 Project EU-Conversion https://cordis.europa.eu/project/id/101163752
174 Project PULSAR https://cordis.europa.eu/project/id/101061251

In the current security context, reinforced by additional requests for support to strengthen capabilities in the context of Russia's war of aggression in Ukraine, the **JRC's expertise in nuclear security and safeguards** will also remain valuable, particularly given its unique mandate at EU level. In light of the foreseen growth for power and non-power applications in the nuclear sector, the Programme's support to nuclear skills, through enduring JRC training opportunities, as well as continued **access to JRC's nuclear infrastructures**, is receiving multiple requests from EU Member States and remains more essential than ever.

The JRC also provide **tools that can be activated and redirected quickly**, such as the tool for the diagnosis and prognosis of hazards in nuclear emergencies (DAPHNE)[175], which has been used in Ukraine to assess radiological risks for nuclear power plants under wartime conditions.

[175] https://joint-research-centre.ec.europa.eu/scientific-activities-z/nuclear-safety/diagnosis-and-prognosis-hazards-nuclear-emergencies-daphne_en

5. WHAT ARE THE CONCLUSIONS AND LESSONS LEARNED?

5.1. Conclusions

The interim evaluation concluded that the Euratom Programme is **successful in supporting pertinent research on nuclear safety**, **security, safeguards, radiation protection, radioactive waste management and fusion energy**. The Programme's direct (JRC) and indirect actions (research grants) continue to be instrumental in addressing challenges faced by Member States in these areas.

The research funded by the Euratom Programme **helps Member States to develop a broad spectrum of applications of ionising radiation, while reducing the risks**. Safety research is essential for those Member States that want to pursue nuclear energy as part of their energy mix, whether domestic or imported, and for those that need reassurance that nuclear power plants in neighbouring countries meet the highest safety standards. The public also stands to benefit from Euratom-funded research on other applications of ionising radiation, in particular in medicine.

Evaluation shows that **Euratom financing is used in an optimal manner**, avoiding unnecessary duplication while providing the required EU-added value, economies of scale, and coordination. In this respect, the Euratom programme remains a key part of the European research landscape.

The Euratom Programme effectively accommodates the diverse needs of all Member States, from small Member States with no civil nuclear programme and almost no nuclear research activities, to large Member States that rely heavily on nuclear power for their energy needs and are at the forefront of nuclear research. Even amongst the 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. Considering these boundary conditions, the evaluation shows that the Euratom-supported actions match these needs.

In the area of nuclear safety, Euratom actions 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).

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. The Programme also addressed the growing interest in small modular reactors (SMRs), by funding research on SMR, with particular focus on their safety features and passive safety systems.

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 further developing co-funded Partnerships in these fields.

Results of Euratom-funded research in fusion are not sufficient to bring fusion energy to the market in time to support EU decarbonisation efforts and to boost competitiveness. It is necessary to identify the critical issues and risks for making the fusion power plant that should drive the Euratom-funded research now and in the next years. The Programme must evolve to address the technology bottlenecks which require additional focus and investment while involving more private financing, industry experience and increasing the international collaboration with reliable partners where there is a clear added value for the EU. The Commission already initiated preparations of a co-programmed European Partnership in this field, bringing together stakeholders in the public and private sectors.

The Council's decision in 2021 to reduce the budget for the programme by 20% limited possibilities to fund excellent research proposals. **It also hampered the JRC's efforts to address the emerging challenges** with the necessary flexibility and capacity at a time of renewed interest in nuclear technologies. Using available funds, the programme addressed new challenges such as research on alternative fuel for Russian-designed reactors used in some Member States, increased strategic autonomy in nuclear materials and data, and support for researchers in Ukraine.

The JRC plays a particular role in the Euratom programme. Its four nuclear sites have provided expertise and facilities to half of the Euratom research projects launched since 2021. They also carry out their own highly relevant research, deliver training and produce analyses. This benefits Member States and provides policy support to the Commission on the whole spectrum of activities, from nuclear safety to security and safeguards. The evaluation highlighted the efforts to improve the JRC's overall efficiency, with the introduction of a new way of working based on portfolios. This has led to better integration of scientific activities. It also noted the implementation of a new nuclear strategy to improve infrastructure management, better cooperate with stakeholders and enhance communication.

5.2. Lessons learned

The evaluation shows that there were limited effective synergies with Horizon Europe due to the lack of specific provisions, systematic screening via a permanent governance structure and different budget levels. Those synergies have mostly been restricted to the use of MSCA fellowships for nuclear researchers and cross-references between the work programmes.

In the future, there should be greater focus on operational provisions to foster specific synergies in a limited number of relevant and complementary fields between the Euratom Programme and R&I FP. Commission services should collaborate closely and devote significant resources to understanding fully the two programmes and finding the best

complementarities. Accordingly, the programming of Euratom and Horizon Europe actions should be closely coordinated, including a systematic screening for opportunities in synergies during preparation of Horizon Europe and Euratom WPs. The Euratom Programme should also be fully integrated into mechanisms providing for synergies between EU spending programmes including with the EU Framework Programme, as well as supporting relevant aspects of SMR Alliance, the new Net-Zero Industry Act (NZIA) and providing science base for the implementation of Euratom legislation.

Based on the observations or proposals for further actions put forward by the external panel of experts[176] who has assessed the JRC's performance under the Euratom programme 2021-2025, several actions were identified as particularly relevant for the JRC to address and/or implement.

As part of its strategy for its nuclear activities and aligned with recommendations from the experts, the JRC has started and will continue "*mapping the state of its nuclear infrastructures to plan for future development*" with a focus on optimising their use and eventually working towards a concentration of experimental activities using highly radioactive materials across two sites. JRC's nuclear research infrastructures are a key asset to the Euratom community and improving the efficiency of their use also requires a sound management of resources. The implementation of the nuclear strategy is also an opportunity for the JRC to reassess some of its activities to prioritise and rationalise work to further enhance impact and relevance under the Programme.

Another proposal for action was for the "*JRC to invest in generalists able to integrate competences across disciplines, while maintaining specialist skills and "blue sky" research for innovation*". It was acknowledged that social sciences had been gradually taken up in the nuclear field, however there is a limit to the integration capacity in all nuclear projects in the face of already strained scientific resources. Thanks to a new portfolio approach to its work programme, the JRC is able to enhance synergies across various research domains leveraging both nuclear and non-nuclear activities.

Experts also encouraged "*the JRC to continue developing foresight capability and to make better use of its current capacities for analysing trends and defining its own nuclear research*". Increasing anticipatory capabilities to predict future policy and technology challenges is in line with priorities defined at European Commission level. The JRC already produces regular horizon scanning exercises and organises foresight workshops with selected stakeholders, which has been highlighted as satisfactory progress towards meeting this recommendation.

Communication is another area of necessary improvement as despite the quality of its research and its role in support to policymaking, "*the JRC can remain somewhat invisible to Member States' administration and the general public*". For instance, "*finding better ways to communicate on safeguards activities under the direct actions, especially their impact on security at global and EU level*" would be beneficial. Communicating on the unique possibilities offered by non-power applications research would likewise give the JRC the opportunity to positively present its research results to policymakers in Member

[176] Heuer, R., et al., Interim evaluation of the activities of the Joint Research Centre under Horizon Europe and Euratom 2021-2025 - Final report of the evaluation panel, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/63710, JRC134811.

States. Enhancing communication efforts is therefore highly recommended and forms a key part of the JRC's nuclear strategy.

Considering the foreseeable large needs in radioactive waste management and decommissioning across a number of EU Member States, it was also observed that "*the JRC could dedicate more resources into this area of research, in particular focusing on repository related activities*". The JRC has maintained successful long-term collaborations with several European stakeholders on spent fuel management and disposal research, making it an especially relevant actor in this important field of studies. A similar key role is expected of the JRC in the area of decommissioning. As already recommended in the ex-post evaluation of the Euratom programme 2014-2020, "*the JRC should provide Member States with scientific knowledge for the definition of their national strategies and assist in the sharing of experiences and good practices*".

Equally essential and underpinning all nuclear activities in the EU is the maintenance of adequate level of skills and competences. Considering current investments and developments in the nuclear field in the EU, education and training opportunities offered by the Euratom programme are of noticeable importance. The panel of experts has observed that "*the JRC should continue supporting the efforts of EU Member States to promote the collection of information for analysing the needs of human resources in the nuclear sector*". Education and training activities could be expanded to more research institutions and universities in the EU thanks to a targeted communication leading to longer stays of students and researchers in JRC facilities and sustainable exchange of staff.

The continued relevance of the Programme, through both indirect and direct actions, is grounded in a constant need to improve nuclear safety, security and safeguards in the EU in view of long-term operation of current nuclear installations, waste and spent fuel management and disposal activities and the foreseen decommissioning of a number of facilities across Member States. The current geopolitical context with Russia's war of aggression in Ukraine has also led to prioritising domestic sources of energy, resulting in a renewed appeal to nuclear energy in several Member States. On the other hand, the overall security situation argues for enhanced nuclear security, safeguards and emergency preparedness capacities. Additionally, development and envisioned deployment of innovative technologies, like SMR within the EU, require stringent adherence to the highest nuclear safety, security and safeguards standards, adding further evidence to the essential role played by the Euratom research and training programme. In the face of those challenges, the Programme's reduced budget limits the ability to fully address all current and foreseen challenges or to cope with new priorities without leaving potentially critical priorities uncovered. Maintaining the necessary nuclear competences and expertise at EU level is also paramount to ensure continued management of unique infrastructures and quality nuclear research, to preserve European technological leadership and independence in the various areas of the nuclear field and to guarantee the highest levels of nuclear safety, security and safeguards.

ANNEX I: PROCEDURAL INFORMATION

1. **Lead DG**: DG RTD, Joint Research Centre
2. **Decide reference** : PLAN/2023/2976
3. **Euratom Work Programme** (financing decision for contracting experts): C(2022) 4240
4. **Organisation and timing:**

   Start of evaluation work by Commission services: Autumn 2022

   The interim evaluation is supported by the external assessments conducted by independent experts which took place from the end of 2022 for the JRC's direct actions and in 2023-2024 for the indirect actions managed by DG RTD.

   Call for evidence and stakeholder consultation: March 2024 - May 2024

   https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14112-Euratom-Research-and-Training-Programme-2021-2025-evaluation_en

   Interservice Steering Group (composed of representatives from ENER, JRC, SG, SJ) received draft SWD in November 2024

   Finalisation of SWD and launch of Inter-Service Consultation: January-February 2025

5. **Consultation of the Regulatory Scrutiny Board (RSB):**

   Evaluation of the Euratom Programme 2021-2025 was not selected for assessment by RSB.

6. **Evidence used together with sources and any issues regarding its quality**:

   The data used in this report in relation to the **direct actions** stem from various sources. These include the JRC's internal databases of publications and other outputs (PUBSY), the JRC's yearly review of its projects and outputs performance called the Productivity and Impact Evaluation (PRIME) and bibliometric indicators derived from the peer-reviewed scientific publications. The results of the interim evaluation assessment conducted by the external panel of experts, as well as answers to the public consultation gathered from stakeholders were also used as further evidence to ground the analysis in this evaluation report. In terms of quality assurance, the work culture at the JRC has progressively developed in line with the ISO 9001 quality standard, integrating its requirements into working practices and creating a harmonized framework called the JRC Integrated Management System across the whole organisation. The IMS integrates the Internal Control Framework and common requirements from various ISO standards currently in use in the JRC, while considering sites specific requirements (national, regional and/or local regulations).

   Evidence used for **indirect actions:**

   - Statistics on the implementation and results of Euratom calls for proposals launched during 2021-2024 (Commission CORDIS database https://cordis.europa.eu/);
   - Periodic and final reports from Euratom projects funded under 2021-2025 Programme (available in Commission CORDIS database https://cordis.europa.eu/);
   - EC assessment of projects' periodic reports (2021-2025)

7. **Use of external expertise**: External expertise input was used to sustain the evaluation report.

The **direct actions** were reviewed by an external panel of experts who assessed the JRC's performance during the first two years of implementation of the Euratom programme 2021-2025 and drew a series of recommendations which are reflected upon in the conclusion of this report. Long-term impact of the direct actions' performance was also analysed through 13 case studies drawn up to highlight specific JRC research activities, independently evaluated by external experts and subjected to the feedback of customer DGs and other stakeholders.

For **indirect actions**, major part of the interim evaluation is based on the assessment made by external experts, who evaluated progress made on the basis of evidence from Euratom-funded projects and interviews with project coordinators. The Commission services used thematic reports prepared by experts appointed following a call for expression of interest:

- Helena Janžekovič (inspector at Slovenian Nuclear Safety Administration) - *Interim Evaluation and Ex-ante Evaluation for Euratom in the Field of Radiation Protection*, June 2024.
- Jean-Paul Minon (former CEO of ONDRAF/NIRAS, Belgian radioactive waste management authority) - *Interim evaluation of Euratom Programme 2021-2025 and ex-ante evaluation of Euratom Programme 2026-2027 in the field of spent fuel and radioactive waste management*, March 2024
- Dr. Eng. Stefano Monti (former Head of the Nuclear Power Technology Development Section of the International Atomic Energy Agency) and Liisa Heikinheimo (former Deputy Director General of Nuclear Energy and Fuels Section at the Finnish Ministry of Economic Affairs), *Interim evaluation of indirect actions for nuclear safety under Euratom Research and Training Programme 2021-2025 and recommendations for 2026-2027 extension*, June 2024
- European Commission, *Summary report - Interim Evaluation of Euratom Fusion Programme 2021-2025 and Ex-ante Assessment of Extension of EURATOM Fusion Programme 2026-2027* (written on the basis of inputs from: Mohamed Abdou (Distinguished professor emeritus in Mechanical and aerospace engineering, Director of Fusion Science and Technology Center at UCLA), Attila Aszodi (Nuclear safety expert and dean of the Faculty of Natural Sciences at the Budapest University of Technology and Economics), Steven Cowley (Director of the Princeton Plasma Physics Laboratory), Julien Vieuble (Nuclear Safety Inspector at ASN)).

Reports 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

The purpose of this interim evaluation is to produce a review of the performance of the Euratom programme 2021-2025 during the first years of implementation and to assess it against the criteria of relevance, efficiency, effectiveness, coherence and EU added value as stipulated in the European Commission's Better Regulation Guidelines for evaluations.

Section 2 on expected outcomes of the Programme was prepared on the basis of impact assessment and explanatory memorandum accompanying the Commission proposal for the 2021-2025, as well as 2023-2025 Euratom Work Programme's chapter on multiannual strategy for Euratom research. 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.

Section 3 on how the situation has evolved over 2021-2024 describe how the Programme was implemented, what has happened in quantitative and qualitative terms using data from the calls for proposals.

Section 4 on evaluation findings explains in detail scientific progress and evolution of research organisation with particular focus on the European Partnerships. Each thematic subsection is based on findings from 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. Where relevant these findings are supplemented by observations from the stakeholder consultation.

Limits of the evaluation – The main limitation of this evaluation is that, at this point, the picture of the Programme's implementation and results can only be partial. Evaluation is taking place during the fourth year of the Programme's implementation when only one of the 58 projects launched between 2021 and 2024 had been closed. In financial terms, as of December 2024, the cumulative implementation rates are 79% for commitments and 40% for payments.

Data limitations include issues related to data availability and measurability of outcomes (e.g. most Euratom Key Performance Indicators (KPI) focus on outputs from research projects such as publications and deliverables), aggregation (e.g. difficulty in aggregating data covering the Programme's whole spectrum coming from various data sources) and reliability of certain data (e.g. data on publications are based on self-reporting by project coordinators). Only partial data is available to the evaluation on the financial support to third parties ("cascading grants"). These grants are not managed through standard Commission IT tools: basic information about participants is submitted in periodic reports by the "first level" beneficiaries arranging the calls but only with a significant delay. For the Euratom co-funded European Partnerships (accounting for 76% of indirect actions), integration in Commission monitoring systems takes place with a considerable time delay.

This limited and, possibly, distorted some of the analysis, especially on the distribution of the funding. 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 thematic coverage and depth. To

overcome and mitigate these limitations, this SWD is transparent in indicating its data sources and all underlying sources are available.

Concerning the direct actions, the evaluation was sustained by the independent assessment submitted by an external panel of nine experts who analysed[177] the JRC's performance and contribution to both the Horizon Europe and Euratom research and training programmes in 2021 and 2022. Three Panel members with relevant expertise, together with the Chair, were responsible for the assessment of activities under the Euratom programme. The interim assessment started at the end of 2022 and was completed in October 2023. It consisted in desk research studying the legal bases, programme documents, past evaluations, performance reports, a JRC report on basic data, and publicly available materials. The panel was handed a list of evaluative questions to guide their analysis and received case studies illustrating the impact of selected JRC activities on science, society and policymaking. Those case studies had been independently assessed by experts from academia, governmental organisations or industry and sustained with constructive feedback from relevant stakeholders. Bibliometric data for benchmarking scientific performance was also presented to Panel members and they led a fact-finding mission comprising a series of hearings with staff and top management at JRC research sites in Ispra and Karlsruhe. Members of the JRC's Board of Governors, as well as key stakeholders from other Commission services and the Committee of the Regions were also interviewed to complement the analysis. The experts provided their views on needed changes and considered the follow-up given to the recommendations of the ex-post evaluation of JRC activities under the preceding Euratom programme.

In order to allow for a comprehensive evaluation, this report also considers bibliometric data, policy and scientific outputs from 2023. The recommendations provided by the external panel of experts served to draw up related conclusions and actions on the way forward that will support the design of the extension proposal for 2026-2027. Additionally, a public consultation was conducted in May 2024 allowing to gather feedback from key stakeholders from the research, academia, industry and public authorities on the implementation of the Euratom programme 2021-2025.

[177] Heuer, R., Florea, A.M., Herranz Soler, M., Janowski, T., Keskitalo, E.C.H., Maas, R., Oddou, J., Pálinkás, J. and Wegener, H., Interim evaluation of the activities of the Joint Research Centre under Horizon Europe and Euratom 2021-2025 - Final report of the evaluation panel, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/63710, JRC134811.

ANNEX III. EVALUATION MATRIX AND, WHERE RELEVANT, DETAILS ON ANSWERS TO THE EVALUATION QUESTIONS (BY CRITERION)

Criteria	Question	Answer	Indicator	Data source
Relevance	Was the programme designed and implemented in line with the needs of EU policymakers, in particular the political priorities of the Commission 2020-2024?	Under the Euratom programme, the external panel generally agreed that the JRC's work made a significant contribution to a stronger and safer Europe. The JRC develops a multi-annual work programme in close consultation with partner DGs and incorporating inputs from Member States authorities and other external stakeholders via formal and informal consultations.	Share of JRC project outputs producing policy-relevant findings	Yearly PRIME exercise JRC Work Programmes (2021-2022; 2023-2024)
	Did the JRC anticipate, and react appropriately to new policy needs and societal challenges?	JRC needs to continue developing its foresight capability and is encouraged to make better use of trend analysis for defining its own research. Yearly horizon scanning exercises on nuclear safety and security were acknowledged as satisfactory progress in this area.	Outcomes of JRC nuclear foresight activities JRC work programme collaborative preparation	JRC Horizon scanning reports

		JRC has introduced changes in its organisational structure to allow more agility and focus on its response to challenges in the social, political, security and economic environment. The structuring of the work programme was altered from 2023 around priority areas managed through project portfolios allowing to enhance the capacity to anticipate new challenges.		
	Have the objectives of the Euratom research and training programme been met?	The JRC's direct actions have made substantial progress towards meeting the objectives of the Euratom programme.	Key Performance Indicators (Euratom Programme 2021-2025)	Euratom Programme Performance Statements
Efficiency	Have the resources been used efficiently to generate the desired changes?	Major cuts in the Euratom programme funding have been acknowledged and are particularly impactful in the face of large demand for research and policy support, as well as the importance of providing education and training to maintain a competent and skilled workforce. In the face of such cuts, JRC undertook a prioritisation and	Implementation plan of the nuclear strategy of the JRC	External panel assessment report

		rationalisation exercise establishing a new nuclear strategy. The external panel of experts supports the JRC's efforts to increase its funding through the Euratom programme to maintain its expertise, services and infrastructure.		
	Has the JRC attributed the funding effectively (in terms of output, quality of research and impact)?	The JRC has adopted efficiency measures through a new strategy for its nuclear activities and the management of its infrastructures in 2021 to align available resources in the existing research areas with the Programme's budget cuts. Part of this strategy focus on prioritisation of nuclear activities to maximise JRC's strategic added value.	Monitoring the implementation of the various actions in the nuclear strategy of the JRC	JRC nuclear strategy and implementation plan
Effectiveness	To what extent have the achievements of the direct actions contributed to meeting the overall and specific objectives of Euratom 2021-2025?	The performance of the JRC's direct actions has been satisfactory, of high quality and producing effective results on the whole scope of nuclear activities defined in the Programme.	Key Performance Indicators (Euratom Programme 2021-2025) Number of trainings delivered; Number of peer-reviewed publications; Number of reference materials delivered;	JRC internal outputs monitoring (publicity: publication management platform) SCOPUS Yearly PRIME exercise JRC impact case studies

			Outputs contributing to international standards; Number of researchers accessing research infrastructures; Number of people benefitting from upskilling; Outputs with policy impact.	
	To what extent are the JRC's processes for planning, monitoring, reporting and evaluation appropriate, effective and transparent?	The JRC is encouraged to keep developing systematic internal self-evaluations, developing key performance indicators for measuring the efficiency of science for policy support, mapping knowledge gaps, SWOT analyses and collecting regular feedback from partner DGs. Based on a recommendation from the ex-post evaluation, JRC should pursue these actions and promote more qualitative evaluation of scientific outputs.	ISO9001 regular external audits	External panel assessment report JRC Annual Activity Report
	How does the JRC's work compare to top-class work in the various nuclear fields done elsewhere?	Impact metrics show that the JRC's work is published in reputable journals. On average from 2021 to 2023, 15,5% of JRC's peer-reviewed publications appear	Key Performance Indicators (Euratom Programme 2021-2025)	JRC Scientific excellence report 2018-2022 Bibliometric analysis of JRC's research

		in the top 10% journals. JRC's publications also relies on a wide network of collaborators. This compares satisfactorily with research and technology organisations conducting nuclear relevant research and is reinforced by JRC's support to policy and the scientific community.	Share of peer reviewed JRC publications in the top journals	performance using Scopus-SciVal tools 2018-2022 SCOPUS SciVal
Coherence	How well do the different direct actions projects work together, internally and with other EU interventions/policies?	The JRC has introduced a new portfolio approach to its work programme, organised around priority areas managed to allow for a cross-disciplinary approach, ensuring better integration across scientific and policy domains. The JRC also implemented an agile working collaboration system. This is an opportunity to enhance coherence and higher policy relevance as activities are integrated in a more complementary way within the JRC. It also fosters closer interactions between Horizon Europe and the Euratom programme. Cluster and operational meetings are regularly organised with	Number of mixed portfolios (nuclear and non-nuclear activities) in JRC Work Programme Number of cluster and operational meetings	JRC Work Programmes (2021-2022; 2023-2024) External panel assessment report

		policy DGs to ensure alignment with EU priorities.		
	How coherent are the direct actions in terms of synergies, overlaps and complementarities with the activities funded under the indirect actions of the research programmes?	The JRC and DG RTD co-draft the Euratom work programmes to ensure synergy. The JRC also actively participates in 63% of projects funded under the indirect actions enhancing collaboration with Member States organisations and ensuring alignment and complementarity with nuclear research priorities. JRC and RTD have also implemented a pilot project providing financing for the open access to JRC nuclear infrastructures, promoting training and mobility for European researchers and facilitating the access.	Participation of JRC in indirect actions of Euratom (percentage of the total actions)	Community Research and Development Information Service (Cordis)
	To what extent has JRC achieved its aim of more holistic approaches and more internal cooperation for policy support?	The new portfolio approach makes use of expertise across the whole JRC in multiple scientific fields and policy areas. Cross-cutting activities such as knowledge management, exploratory research, foresight, education and training run through all the portfolios, including in so-called mixed portfolios	Number of mixed portfolios (nuclear and non-nuclear activities) in JRC Work Programme	JRC Work Programmes (2021-2022; 2023-2024) External panel assessment report.

		(nuclear and non-nuclear activities). This more holistic approach had led to greater coherence and efficiency.		
EU added value	What is the added value resulting from the direct actions compared to results from interventions taking place at regional or national levels?	The JRC, with its unique expertise and infrastructure, is an important complement to Member States capacity to deal with nuclear issues ranging from nuclear safety to security and safeguards, to non-power applications. The open access scheme and education and training offers have a high EU added value, contributing to the independence of research in Europe. The JRC is hosted in different member states and brings opportunities for collaboration in research and awareness raising for science closer to the regional and national communities.	Public consultation	External panel assessment report Reports on Open Access Programme Results of Public Consultation
	To what extent does the JRC research and policy support provide added value beyond what is being done in Member States?	The JRC education and training projects and policy support provide critical added value complementing and going beyond Member States capacities. For instance, policy support builds a sound basis for monitoring nuclear activities,	Number of trainings delivered Number of policy items supported by the direct actions	External panel assessment report Yearly PRIME exercise

		training in nuclear security enhances the surveillance of trafficking of radioactive materials and activities in education and training contribute significantly to maintaining and developing nuclear competencies in the EU and the Member States.	Number and Share of projects producing policy-relevant findings	

ANNEX IV. OVERVIEW OF BENEFITS AND COSTS

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 benefits for EU society from scientific impact	one off	No estimate available			Peer-reviewed publications: ca. 2000 in 2021-2024 More than 7200 researchers participated in joint exploitation of nuclear research facilities in the EU 986 PhD students in nuclear research benefitted from Euratom	Direct scientific/training outputs of Euratom (Figures as of 31/12/2024)		

Nuclear safety: improved designs for future nuclear power plants, guidance for nuclear power plants operators and for safety authorities development of retrofitting of safety features into existing NPPs
Radioactive waste management: development of safety case for deep geological storage of medium and high level waste development of safe solutions for other waste streams and for interim storage of waste
Radiation protection: better understanding of low dose impact on public health; development of medical and other applications of radiation
Nuclear security and safeguards: More effective and efficient safeguards implementation & reduction of nuclear security risks
Fusion energy development: Progress towards demonstration of feasibility of fusion as energy source

						financial support. 962 students benefitted from Euratom mobility support 3324 persons trained by JRC			

II. COSTS									
		Citizens/ EU Society		EU Public Administration		Euratom Beneficiaries		Euratom Applicants	
		Quantitative	Comment	Quantitative	Comment	Quantitative	Comment	Quantitative	Comment
1. Direct economic cost of R&I funding to EU society (Operational Expenditure)	one off	€ 671 million	Operational expenditure of Euratom (committed appropriations during 2021-2024)						
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.	€ 429 mio	Administrative expenditure of Euratom programme (committed appropriations for direct and indirect actions, 2021-2024)				
3. Beneficiaries' administrative costs of participation	one off					€122-163 mio	Administrative costs per participation incurred to meet requirements		

(Not additional - already included in no.1 Operational Expenditure)						9% - 12 % of the total project	(Monetised order-of-magnitude estimate based on)		
4. Costs of applications Direct costs of preparing proposals of successful and unsuccessful applicants	one off							€18 000 to €37 000	Cost per proposal (evidence from interim evaluation of Horizon Europe

ANNEX V. STAKEHOLDERS CONSULTATION - SYNOPSIS REPORT

1.Introduction

The **Euratom Research and Training Programme (2021-2025)** was initiated as part of the European Union's broader efforts to enhance nuclear safety, foster innovation, and drive research within the European nuclear energy sector. This programme is integral to supporting Europe's long-term energy security goals and aligns with the EU's commitment to achieving carbon neutrality by 2050. Considering its significance, the European Commission initiated a comprehensive review of the programme, evaluating its performance during 2021-2025 and considering an extension for the years 2026-2027. This evaluation involved a broad range of stakeholder consultations, including participants from industry, academia, research institutions, public authorities, and non-governmental organizations (NGOs).

The primary aim of the consultations was to assess the programme's effectiveness in promoting nuclear research, innovation, and safety, while also determining its alignment with the EU's broader energy goals. As Europe grapples with the challenges of reducing carbon emissions while ensuring energy security, nuclear energy—particularly through advancements in nuclear technologies such as **fusion energy**, **Small Modular Reactors (SMRs)**, and **Advanced Modular Reactors (AMRs)**—is expected to play an increasingly pivotal role. This report consolidates the key findings from these stakeholder consultations, offers an analysis of the programme's strengths and challenges, and outlines recommendations for the 2026-2027 extension.

2.Background

The **Euratom Research and Training Programme** is a crucial pillar of the EU's broader energy and climate strategy. Launched as part of the European Union's response to the growing need for energy security and environmental sustainability, Euratom has consistently contributed to the development of cutting-edge nuclear technologies, improved nuclear safety and security standards, and strengthened Europe's leadership in global nuclear research.

The **2021-2025 phase** of the programme focused on several key areas, including research on nuclear systems, fusion energy, and radiation protection. The programme also aimed to promote international cooperation in nuclear research, facilitating collaborations between EU Member States, associated countries, and global partners. Stakeholders engaged in the 2024 consultation process underscored the programme's importance, particularly considering its contribution to the EU's overarching goal of transitioning to a **carbon-neutral economy by 2050**. As the energy landscape evolves, nuclear energy is seen as a vital component of Europe's energy mix, offering a dependable, low-carbon source of power that can complement renewable energy sources such as wind and solar.

The interim evaluation of the **Euratom Programme (2021-2025)** highlighted several successes, including enhanced cooperation between research institutions, increased

international visibility for European nuclear research, and progress in key areas such as nuclear safety, security and radiation protection. However, challenges such as limited financial resources, complex application processes, and declining budgets for nuclear safety research were also identified. These challenges will need to be addressed in the proposed extension of the programme for **2026-2027** to ensure that Europe remains at the forefront of nuclear innovation and safety.

3.Consultation Activities

The consultation process for the **2026-2027 extension** of the Euratom Programme was designed to ensure the inclusion of diverse perspectives from all relevant stakeholders. Following the European Commission's **Better Regulation Guidelines**, the consultation employed multiple methods to gather input, including public consultations, targeted consultations, and a **Call for Evidence**. Each of these activities was crucial in capturing the nuanced views of stakeholders across Europe and beyond.

- **Public Consultation**: Conducted via the **"Have Your Say" platform**, this method allowed for wide public engagement. Structured questionnaires and written comments were collected from various stakeholders, including industry professionals, academics, researchers, NGOs, and individual citizens. This approach facilitated broad participation and ensured that the consultation process was transparent and inclusive.
- **Targeted Consultations**: Key stakeholders from industry and academia were engaged directly through interviews, workshops, and written submissions. Entities such as **EDF**, **NuclearEurope**, and the **Fusion Industry Association** played a significant role in these targeted consultations, offering detailed insights into the current state of nuclear research and the future needs of the industry.
- **Call for Evidence**: A **targeted call for evidence** was issued to collect technical and scientific data relevant to the evaluation of the existing regulatory framework. The contributions from stakeholders such as **Orano**, the **CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives)**, and **EURAMET (European Association of National Metrology Institutes)** were crucial in highlighting the need for enhanced support for nuclear innovation and safety research.

The consultation period spanned 12 weeks, providing ample time for stakeholders to contribute their insights. The comprehensive nature of the consultation activities ensured that all relevant perspectives were considered, enabling a thorough evaluation of the programme's impact and future potential.

4.Key Findings from the Public Consultation

The results of the 2024 public consultation provided valuable insights into the effectiveness of the Euratom Programme and highlighted several key areas for improvement. The consultation revealed a prominent level of stakeholder participation in Euratom-funded projects and identified both the benefits and challenges associated with the programme.

4.1.Participation in Euratom Projects

A significant **75%** of respondents indicated active participation in at least one Euratom-funded project during the 2021-2025 period. This high level of engagement demonstrates

the programme's broad appeal and relevance to the European nuclear research community. Additionally, **73.85%** of respondents had participated in earlier iterations of the Euratom Programme, reflecting the programme's long-standing role in fostering collaboration and innovation in nuclear research.

4.2.Research Areas of Focus

The consultation revealed that the majority of stakeholders (**63.08%**) were involved in **nuclear systems research**, particularly in areas related to **fuel cycle technologies**. This focus aligns with the EU's goals of enhancing nuclear safety and improving the efficiency of nuclear energy production. In addition to nuclear systems research, other areas such as **radiation protection** (**34.87%**) and **fusion energy research** (**32.82%**) received significant attention, underscoring the importance of a diverse and multi-faceted approach to nuclear research.

4.3.Benefits of Participation

Stakeholders identified several key benefits of participating in the Euratom Programme. The most commonly cited benefit was **enhanced cooperation with international partners** (**78.97%**), which has facilitated cross-border research collaborations and contributed to the global visibility of European nuclear research. Other significant benefits included **increased international visibility** (**36.41%**) and **support for projects not feasible at the national level** (**35.38%**).

4.4.Challenges and Barriers

Despite the programme's successes, stakeholders also identified several challenges. The **complex application process** was a major concern, with **40.51%** of respondents finding it burdensome. Additionally, **limited financial resources** and **inadequate awareness of the programme** were cited as significant barriers by **35.9%** of participants. These challenges highlight the need for administrative streamlining and increased outreach to ensure that the programme remains accessible to a broader range of stakeholders.

4.5.Contributions from the Joint Research Centre (JRC)

The **Joint Research Centre (JRC)** was recognized as pivotal in driving nuclear research in the Euratom Programme with respondents highlighting the JRC's expertise on current and innovative nuclear technologies, as well as its contribution to maintaining competences at EU level. The main identified benefits of the direct actions were the possibility of **collaboration and access to JRC** expertise for **46.67%** of respondents, the **production of independent and high-quality research** for **31.79%**, as well as the opportunity to **access unique nuclear infrastructures** for **33.33%** of participants. This emphasizes JRC's importance in maintaining Europe's leadership in nuclear innovation. The valuable **provision of education and training opportunities** by the JRC was also underlined by **20%** of respondents.

4.6.Relevance of Funding Priorities

The consultation revealed support for the **funding priorities** of the Euratom Programme, with **45.13%** of respondents strongly agreeing that nuclear safety, particularly for operating plants, should remain a top priority. Additionally, there was widespread recognition of the need to support emerging technologies such as **fusion energy** and **new reactor designs**, which are critical for the EU's future energy strategies. Stakeholders emphasized that these technologies offer the potential for safer, more efficient nuclear energy production and are essential for meeting Europe's long-term energy and climate goals.

4.7.Satisfaction with Project Implementation

In terms of project implementation, nearly half of the respondents (**48.21%**) agreed that the project monitoring and reporting mechanisms were adequate. Furthermore, **35.9%** of respondents provided positive feedback on the **European Commission's support** during the grant preparation phase, indicating a generally prominent level of satisfaction with the administration of the programme.

5.Stakeholder Participation

The 2024 consultation attracted a diverse array of stakeholders[178], each bringing unique perspectives on the future of nuclear energy in Europe. These stakeholders included industry representatives, research and academic institutions, public authorities, regulatory bodies, non-governmental organizations (NGOs), and the general public.

For the most part, they were research organisations, universities and industries whose main expertise and interest lay in the field of nuclear safety for existing and future nuclear technology. For instance, in the area of safeguards, regulatory authorities are usually the responsible organisations, while ministries or law enforcement authorities deal primarily with nuclear security aspects. Similarly, the safe management of spent fuel and radioactive waste, as well as decommissioning activities are usually managed nationally by specific organisations. Few such actors featured among the responding organisations.

5.1.Industry Representatives

Industry stakeholders, including **NuclearEurope** and the **Fusion Industry Association**, emphasized the importance of maintaining a balanced approach to funding nuclear technologies. While **fusion energy** has garnered significant attention for its long-term potential, industry representatives stressed the need to continue supporting **fission technologies**, which are crucial for Europe's immediate energy security needs. The development of **Small Modular Reactors (SMRs)** and **Advanced Modular Reactors**

[178] Most stakeholders' expertise and activities lay in the nuclear safety field. Entities with competences on safeguards and nuclear security (regulatory authorities, ministries or law enforcement authorities) were less represented.

(AMRs) was seen as particularly important, as these technologies offer the potential for safer and more flexible nuclear energy generation.

5.2.Research and Academic Institutions

Research and academic institutions provided valuable insights into the **scientific and technical aspects** of nuclear research. Stakeholders from the academic sector advocated for continued investment in **radiation protection** and **fusion energy** research, emphasizing the importance of sustained funding to ensure that Europe remains a leader in these critical areas. Additionally, the need for enhanced **research infrastructure** and greater support for **cross-border collaborations** was highlighted.

5.3.Public Authorities and Regulatory Bodies

Public authorities and regulatory bodies, such as the **German Federal Office for Radiation Protection**, highlighted the importance of maintaining high **safety standards** in nuclear energy production. These stakeholders called for a unified European approach to radiation protection and emphasized the need for robust enforcement mechanisms to ensure that safety standards are upheld across all EU Member States.

5.4.Non-Governmental Organizations (NGOs)

NGOs raised concerns about the **environmental and safety implications** of nuclear energy. While many NGOs acknowledged the potential benefits of nuclear power in reducing carbon emissions, they also stressed the importance of stringent **environmental regulations** and **transparent decision-making processes**. Several NGOs called for greater public engagement in the regulatory process to build trust and ensure that the public's concerns are adequately addressed.

5.5.General Public

The general public's feedback reflected a mix of support and opposition to nuclear energy. While some citizens recognized the role of nuclear power in achieving **carbon neutrality**, others raised concerns about **nuclear safety**, **long-term waste management**, and the risks associated with **nuclear accidents**. Public participants called for improved **transparency** in regulatory processes and clearer communication of the Euratom Programme's goals and outcomes to foster greater public trust in nuclear energy.

6.Key Themes Emerging from Consultation

The consultation process identified several key themes that are critical to shaping the future direction of the Euratom Research and Training Programme. These themes reflect the diverse priorities of stakeholders and the challenges and opportunities facing the nuclear energy sector in Europe.

6.1. Safety and Environmental Impact

The paramount concern for the majority of stakeholders was the **need to maintain and enhance nuclear safety standards**. Ensuring that nuclear energy production adheres to

the highest safety standards is essential not only for the protection of human health but also for maintaining public confidence in nuclear technology. **44.62%** of respondents agreed that progress was being made in nuclear safety, but they also emphasized that more could be done to improve the regulatory frameworks governing nuclear energy production.

In addition to safety, **environmental impact** emerged as a key theme. Stakeholders called for stringent environmental regulations to mitigate the potential ecological risks associated with nuclear energy. While nuclear power is recognized as a low-carbon energy source that can contribute to reducing Europe's greenhouse gas emissions, it also poses challenges related to **nuclear waste management** and **radiation protection**. Several participants urged the European Commission to strengthen regulations on these fronts and to prioritize research into technologies that minimize environmental risks, such as **advanced reactor designs** and **improved fuel cycle management**.

6.2 Innovation and Technological Advancement

Innovation is seen as a critical driver for the future of nuclear energy in Europe. **Fusion energy**, in particular, was highlighted as a long-term solution to Europe's energy security challenges. Fusion technology promises to deliver a nearly limitless, clean source of energy, but it remains in the research and development phase. Stakeholders from both industry and academia emphasized the need for **increased funding for fusion research** and called for greater public-private partnerships to accelerate the **commercialization of fusion energy**.

In addition to fusion, stakeholders underscored the importance of investing in **emerging technologies** such as **Small Modular Reactors (SMRs)** and **Advanced Modular Reactors (AMRs)**. These technologies offer the potential for more flexible and scalable nuclear energy solutions, which are particularly suited to addressing Europe's diverse energy needs. SMRs, for example, can be deployed in remote or off-grid locations, providing a reliable source of power where traditional large-scale nuclear plants may not be feasible. The development and deployment of these technologies will require **sustained investment** and **regulatory support**, both of which were highlighted as critical to ensuring Europe's leadership in the global nuclear industry.

6.3 Relevance of direct actions research

The respondents provided insights in the most relevant areas of JRC research in order to meet current and future challenges in the nuclear fields, such as (1) **nuclear knowledge and competences**, comprising education and training, as well as capacity building and the access to nuclear infrastructures; (2) **Safety assessment of new reactor designs and technologies** (SMRs, Gen IV, innovative fuels and materials); (3) **Safety of operating nuclear reactors** (fuel and structural materials, LTO) and (4) **Cross-cutting actions** on nuclear and structural materials, modelling and simulation, nuclear data, digitalisation, harmonisation of safety requirements, certifications and standards.

Other areas like spent fuel and radioactive waste management and decommissioning, radiation protection and emergency preparedness, non-power applications of nuclear technologies and safeguards and non-proliferation were indicated as important by a bit less than 50% of respondents.

6.4 Regulatory Coherence

Many stakeholders called for greater **regulatory coherence** across the EU. There is a need for alignment between **EU regulations** and **international standards** to ensure that Europe remains competitive in the global nuclear market. Stakeholders from the nuclear industry, in particular, emphasized the importance of harmonized regulations to facilitate cross-border collaborations and reduce barriers to the development and deployment of new nuclear technologies.

Additionally, the need for **clearer and more consistent regulatory processes** was a recurring theme. Several stakeholders pointed out that the regulatory framework governing nuclear energy in Europe can be complex and burdensome, particularly for smaller research institutions and start-ups. Simplifying the regulatory processes and providing greater **administrative support** to applicants would encourage broader participation in the Euratom Programme and help accelerate the development of innovative nuclear technologies.

6.5 Public Transparency and Trust

Public trust in nuclear energy remains a significant challenge for the industry. Several stakeholders noted that **public transparency** is essential for building trust and fostering greater public support for nuclear energy. This includes not only transparency in the **regulatory process** but also in the communication of **nuclear safety standards**, **research outcomes**, and the **environmental impacts** of nuclear energy production.

There was a strong call for the European Commission to improve its **communication strategies** and to engage more actively with the general public. Many participants suggested that the Commission should take a more proactive approach in explaining the benefits of nuclear energy, particularly in the context of Europe's **energy transition** and its role in achieving **carbon neutrality by 2050**. Enhanced transparency and public engagement would help address some of the concerns raised by citizens during the consultation, particularly regarding **nuclear waste management** and the risks of **nuclear accidents**.

6.6 Diverging Views on Fission and Fusion

The consultation revealed **diverging views** on the future focus of the Euratom Programme, particularly with regard to the balance between **fission** and **fusion technologies**. While fusion energy is widely seen as the future of nuclear power, many stakeholders stressed the importance of continuing to support **fission technologies**, which remain critical for Europe's immediate energy security needs. Fission technology is well-established and provides a reliable source of low-carbon energy, which is essential for reducing Europe's reliance on fossil fuels.

Industry stakeholders, particularly those from **NuclearEurope**, emphasized the need for a **balanced approach** to funding, ensuring that both fission and fusion technologies receive adequate support. This is particularly important given that fission technology is currently the only viable option for large-scale nuclear energy production. While fusion holds great promise for the future, it is still several decades away from commercialization, making it

essential to continue investing in **fission-based innovations**, such as **SMRs** and **AMRs**, to meet Europe's energy needs in the near term.

7. How Stakeholder Input Has Been Considered

The feedback gathered during the 2024 consultation has been carefully analysed and incorporated into the European Commission's ongoing review of the Euratom Research and Training Programme. The insights provided by stakeholders have informed several key areas of focus for the proposed 2026-2027 extension of the programme.

7.1 Revision of Safety Standards

In response to the strong emphasis placed on **nuclear safety** by stakeholders, the European Commission is considering revising the existing **safety standards** to incorporate new technological advancements and address environmental concerns more effectively. These revisions will aim to ensure that nuclear energy production remains safe and environmentally sustainable, particularly considering emerging technologies such as SMRs and fusion energy. The feedback also highlighted the need for a **more balanced allocation of funding** between fusion and fission research, a point that the European Commission will address in its future budgetary planning.

7.2 Increased Support for Fusion Research

Given the significant support for fusion energy among stakeholders, the European Commission is likely to **increase funding** and **regulatory support** for fusion research in the coming years. This will align with the EU's long-term energy strategy, which envisions fusion as a key component of Europe's future energy mix. **Public-private partnerships** will be critical in accelerating the commercialization of fusion technology, and the European Commission is expected to explore new ways of facilitating such partnerships through the Euratom Programme.

7.3 Enhancement of Transparency Measures

To address the concerns raised about **transparency**, the European Commission will implement measures to improve **public communication** and ensure that stakeholders are better informed about the regulatory processes and the outcomes of Euratom-funded projects. This will include providing clearer information on **project evaluations**, **funding decisions**, and the **environmental impacts** of nuclear energy research. The goal is to foster greater **public trust** in nuclear energy by making the programme's objectives and achievements more accessible to the general public.

7.4 Focus on Workforce Development

Stakeholders also emphasized the importance of investing in **workforce development** to ensure that Europe's nuclear sector has the skilled professionals it needs to maintain its leadership in nuclear research and innovation. The European Commission will explore new initiatives to support skills development, such as the proposed **Nuclear Passport** programme, which would provide standardized training and certification for nuclear

professionals across Europe. By fostering a highly skilled workforce, the Euratom Programme can help ensure the **long-term sustainability** of Europe's nuclear industry.

7.5 Alignment with Other EU Initiatives

Another key recommendation from stakeholders was the need to align the Euratom Programme more closely with other **EU research and development initiatives**, such as **Horizon Europe**. By fostering **synergies** between these programmes, the European Commission can ensure that the Euratom Programme's funding is used efficiently and that the research conducted under Euratom contributes to the EU's broader goals of **scientific excellence** and **technological innovation**.

7.6 Priority areas in focus for direct actions

Based on the survey results, it was determined that the JRC should invest more resources on a few dedicated topics for the extension of the Euratom programme 2026-2027 to continue playing a vital role in advancing nuclear research at EU level. Those topics related to (1) the **safety and security assessment of advanced nuclear systems** (SMRs, AMRs), paramount to ensuring the safe and secure deployment of these technologies; (2) the **development and enhancement of nuclear research infrastructures** (including the Open Access programme) and (3) the **safety and security of current nuclear systems**, which is an ongoing priority requiring constant research and development efforts.

To a slightly lesser extent, spent fuel and radioactive waste management, as well as non-power applications, were also identified as areas warranting significant focus. All these priorities align with the evolving landscape of nuclear technologies and the need to address emerging challenges and opportunities.

9. Conclusion and Next Steps

The feedback from the stakeholder consultations has provided valuable insights into the future direction of the Euratom Research and Training Programme. Stakeholders overwhelmingly supported the extension of the programme for **2026-2027**, emphasizing the need for continued funding, streamlined administrative processes, and enhanced collaboration between industry, academia, and public authorities.

Moving forward, the European Commission will develop a **draft proposal** for the revised regulations governing the 2026-2027 extension. This proposal will reflect the key priorities identified through the consultation process, including **nuclear safety**, **technological innovation**, **transparency**, and **workforce development**. The European Commission will also ensure that all stakeholders are kept informed of how their contributions have been utilized in shaping the future of the programme, reinforcing the EU's commitment to **transparent** and **inclusive** policymaking.

As the Euratom Programme moves into its next phase, it will play a critical role in advancing Europe's nuclear research and energy goals. By investing in **emerging technologies**, **enhancing safety standards**, and **fostering international cooperation**, the programme will help ensure that Europe remains a global leader in **nuclear innovation** and **safety**. The **balance between fusion and fission research**, alongside a commitment

to safety and transparency, will be central to the programme's success in contributing to the EU's goal of **carbon neutrality by 2050**.

10. Recommendations

Based on the findings of the stakeholder consultations, the following recommendations are made for the 2026-2027 extension of the Euratom Research and Training Programme:

- **Increase funding** for nuclear research, with a particular focus on **fusion energy** and **SMR/AMR technologies**.
- **Simplify the application process** and improve administrative support to ensure that a broader range of stakeholders can participate in the programme.
- **Enhance transparency** in regulatory processes and decision-making to build greater public trust in nuclear energy.
- **Invest in workforce development** through initiatives such as the **Nuclear Passport** to ensure that Europe has the skilled professionals needed to maintain its leadership in nuclear research.
- **Align the Euratom Programme** more closely with other EU initiatives, such as **Horizon Europe**, to maximize synergies and ensure efficient use of funding.
- **Focus on priority areas** such as development and enhancement of European nuclear infrastructures.

By following these recommendations, the European Commission can ensure that the Euratom Programme continues to play a vital role in advancing Europe's energy and climate goals, while maintaining the highest standards of **nuclear safety** and **innovation**.

The European support to research in fusion energy has been re-organised on a new basis in 2014 with the creation of a European Co-funded partnership, named EUROfusion.[179] This is managed by the Euratom Research Unit in DG RTD through grant agreements. Following an independent experts' evaluation of the proposal submitted by the EUROfusion consortium, the European Commission agreed to a second grant covering the period 2021-2025 under the corresponding Euratom Work Programme[180]. Currently, the grant amounts to EUR 549 million with an EU contribution covering 54.88% of the total costs. Euratom funding is paid in annual instalments (see Table 1), subject to EUROfusion's achievement of predefined milestones and submission of relevant deliverables. There is some delay in the implementation of the project which implies a lower consumption of budget in comparison with the planning foreseen but it will be solved with a grant amendment (to be signed in 2025) to prolong the duration of the project and let more time to the coordinator to implement the tasks.

Table 1 – Budget for EUROfusion	
	Euratom instalments paid
2021	EUR 102 000 000
2022	EUR 55 579 924
2023	EUR 84 322 365
2024	EUR 107 451 753

Source: EUROfusion

The EUROfusion grant agreement provides for five central bodies of the partnership: the General Assembly, the standing committee called Bureau, a Coordinator to liaise with the EC, a Scientific and Technical Advisory Committee, and a Programme Manager. The implementation of the grant is defined in 26 Work Packages (WP): 7 are on fusion science, 15 on fusion technology and the remaining concern communication, education, technology transfer and public engagement. A more detailed explanation of the work packages, the missions addressed, and the PMU department is described on pages 93-94.

The activities of the Partnership are monitored through 278 contractual deliverables, which are described in the Grant Agreement. In July 2024, around 43% of the relevant documentation was provided and reviewed by the Fusion Sector of the Euratom Research Unit. Additionally, the general progress in the implementation of the grant agreement is marked by 175 predefined milestones. By December 2024, the achievement rate of this parameter reached around 56% (see Table 2 below).

[179] The following analysis is based on the information provided by the EUROfusion consortium through deliverables.

[180] It was a grant to named beneficiary provided in the Euratom Work Programme 2021-2025 (C(2021)4201). 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.

Table 2 – Milestones achieved by EUROfusion	
Years	**Milestones**
2021	19 milestones (11% of the total)
2022	41 milestones (23% of the total)
2023	83 milestones (47% of the total)
2024	98 milestones (56% of the total)

Source: EUROfusion

An overview of the main achievement expected and obtained in 2021-2023 associated with milestones and divided by the various work packages are reported below (Table 3) .

Table 3 - Expected main outputs and results of the Euratom Programme 2021-2025 in fusion energy research

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;

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):

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):

Operation of the W7X facility.

Source: EUROfusion

The various roadmap's missions are linked with the EUROfusion Work Packages according to the table 4 below. The results obtained in the various Work Packages are reported below for both fusion science and fusion technologies.

Table 4 – Fusion Roadmap's missions and EUROfusion Workpackages			
#	**Work Package**	**Missions addressed**	**EUROFUSION Department**
1	Tokamak Exploitation (WPTE)	1,2,4	Plasma Science for ITER, DEMO and stellarators
2	JT-60SA Exploitation (WPSA)	1,2	Plasma Science for ITER, DEMO and stellarators
3	W7-X Exploitation (WPW7X)	1,2	Plasma Science for ITER, DEMO and stellarators
4	Advanced Computing (WPAC)	1-8	Digital Solutions for Fusion
5	Plasma Wall Interaction and Exhaust (WPPWIE)	2,3,6,8	Plasma Science for ITER, DEMO and stellarators
6	Preparation of ITER Operation (WPPrIO)	2,6	ITER Technology and DEMO Preparation
7	Enabling Research (WPENR)	1-8	Digital Solutions for Fusion
8	Design Activities (WPDES)	1-6	ITER Technology and DEMO Preparation
9	Magnet system (WPMAG)	6	ITER Technology and DEMO Preparation
10	Breeding Blanket (WPBB)	3,4,6	ITER Technology and DEMO Preparation
11	Plant Electrical Systems (WPPES)	6	Innovation, DEMO and Fusion Power Plants
12	Divertor (WPDIV)	2,6	Innovation, DEMO and Fusion Power Plants
13	Heating and Current Drive systems (WPHCD)	6	Innovation, DEMO and Fusion Power Plants
14	Tritium, fuelling & vacuum systems (WPTFV)	6	ITER Technology and DEMO Preparation
15	Heat transfer, balance-of-plant and site (WPBOP)	6	Innovation, DEMO and Fusion Power Plants
16	Diagnostic and control (WPDC)	1,6	Innovation, DEMO and Fusion Power Plants
17	Remote Maintenance Systems (WPRM)	6	ITER Technology and DEMO Preparation
18	Materials (WPMAT)	3,6	Innovation, DEMO and Fusion Power Plants
19	Safety and Environment (WPSAE)	5,6	Innovation, DEMO and Fusion Power Plants
20	Early Neutron Source (WPENS)	3	Innovation, DEMO and Fusion Power Plants
21	Prospective Research & Development (WPPRD)	1,2,8	Innovation, DEMO and Fusion Power Plants
22	Socio-Economic Studies (WPSES)	1-8	Programme Manager Office
23	Communication (WPCOMM)	1-8	Programme Manager Office

24	Training and Education (WPTRED)	1-8	Industry Relations and Support Office
25	Programme Management Unit (WPPMU)		
26	Technology Transfer (WPTT)	1-8	Industry Relations and Support Office

Source: EUROfusion

The **progress on the Work Packages provides an overview of the roadmap implementation.** Of the seven fusion science Packages, three deal directly with fusion facilities in Europe and worldwide. Tokamak machines such as JET (Joint European torus) and JT-60SA (Japan Torus-60 Super Advanced), the first superconducting torus in Japan, performed experiments essential for the understanding of future ITER scenarios. Meaningful results are obtained in those facilities: in the field of DT plasma operation, plasma material interaction diverted and achieved plasma current. The studies in stellarator W7-X (Wendelstein 7-X) and in the other facilities grant optimisation and understanding of a different type of facility for potential future fusion power plants operation. Other Packages in the same domain deal with advanced computing for code and model development and infrastructure and support, such as the study of the Plasma Wall Interaction and Exhaust, which gain more importance with the change from Beryllium to Tungsten wall. The last two horizontal WPs aimed at promoting fundamental understanding and longer perspective research over four areas (inertial fusion, materials, theory & modelling and technology & system) and to coordinate European participation in a single EU team approach that covers the whole ITER operation; the goal of this last one is to reach Q=10 as soon as possible once the construction is completed.

The WPs on fusion technology research covered a wide range of areas, such as the assessments of technical feasibility, reliability, safety, maintainability and costs of the future facility. This information can be progressively undertaken for ITER and the safety for the DEMO, helping in developing its design and preparing the preliminary safety report for its licensing together with the alternative and risk-mitigating technology options for DEMO and/or a fusion power plant. The studies have been carried out on magnetic systems, covering both the architecture and the technology R&D, aiming at an integrated superconducting system. The also looked at the development of the Breeding Blanket (BB) and Tritium Extraction and Removal (TER) systems and future integration in DEMO. Finally, the Plant Electrical System, to define the PES requirement for the future fusion plant and progress with the PES conceptual design have been considered. Important developments have been reached for the divertor in different facilities, particularly for W7-X and JT60-SA, and on the conceptual design of all the fuel cycle systems and the systems for non-fuel-type gases (matter injection and vacuum systems. Similarly, characterization and qualification of materials suitable for main DEMO components and the ITER TBM has been carried out, and the design of Remote Maintenance Equipment (RME) has progressed for actual and future tokamaks. Heating, Current Drive, Heat Transfer, Balance-of-Plant and Site have been studied for the Conceptual Design Phase following the design baseline evolution of the DEMO fusion power plant. Finally, a feasible, integrated concept design of the DEMO diagnostics and control system to provide reliable plasma control in accordance with the DEMO control requirements has been carried out, and essential improvement has been reached for the early neutron source WP, which aimed to start the DONES construction phase.

Publications - Over 2021-2023, EUROfusion's research results were published in peer-reviewed journals or conference proceedings (see Table 5). The partnership quadrupled the number of publications in the first three years of the partnership. In 2024, additional 542 papers have been submitted. Moreover, the EUROfusion researchers participated in 497 international conferences since 2021, demonstrating the worldwide relevance of this European Partnership. Highlight events were the Fusion Energy Conference of the International Atomic Energy Agency, the Symposium on Fusion Engineering (SOFE), the Fusion Nuclear Technology International Symposium (ISFNT), the International Conference on Fusion Reactor, and the Symposium on Fusion Technology (SOFT).

Table 5 – EUROfusion peer-reviewed publications					
	2021	**2022**	**2023**	**2024**	**Total**
Publications	190	521	798	542	2501

Source: EUROfusion

In education and training, EUROfusion is entrusted with the support of young researchers and the creation of resources for building knowledge on nuclear fusion. At the graduate level, it has supported on average 218 master's students in 2021-2023. At the postgraduate level, it has supported on average 655 doctorates in 2021-2022 and has increased this number to 819 in 2023, a considerable achievement that exceeds the levels attained under the previous grant agreement. This aspect is cardinal to the formation of a specialised workforce for future fusion reactors.

Table 6 - Number of PhD students supported by EUROfusion							
Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
PhD students	751	751	726	734	672	638	819

Source: EUROfusion

At the postdoc level, EUROfusion offers grants to back excellence and career development in physics (Bernard Bigot Researcher Grants, 3 years) and engineering (Engineering Grants, 3 years). Since 2021, 42 EEGs and 42 ERGs have been assigned in total, including the 16 EEGs and 10 ERGs that are expected to start in 2024.

Table 7 - Engineering Grants (EEG) and Researcher Grants (ERG) awarded by EUROfusion								
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Engineering Grants (EEG)	17	21	16	16	21	-	15	11
Researcher Grants (ERG)	11	12	11	11	11	11	10	11
Total	28	33	27	27	32	11	25	22

Source: EUROfusion

In terms of mobility, EUROfusion has accomplished a 40.9% increase in the number of researchers using research facilities in other laboratories, if compared with the previous grant agreement (see table 8). Currently, EUROfusion offers opportunities to access 8 major infrastructures across Europe. Mobility encompasses funding for visiting scientists for joint research, long-term secondees, and fellowships. In addition, joint research

activities have been approved with a project-oriented approach. This new prospect has been directly integrated into the programme budget under the responsibility of each Project Leader and Taskforce Leader.

Table 8 - Number of fusion researchers with access to research infrastructures through Euratom Programme support							
Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Researchers	909	1 350	1 456	1 734	1 926	2 473	2 443

Source: EUROfusion

Moreover, the attempt to improve the quality of the educational offers on fusion energy in Europe has seen EUROfusion committed to identify the educational needs of the learners and build new study tools. The partnership works in collaboration with the beneficiaries, which are most often universities, and attempts to maintain an updated overview of the educational offer in Europe regarding fusion. Moreover, the collection of data through Human Resources Surveys offers a view on fusion research in terms of gender equality, transnational mobility, qualifications, and career path. The response to these challenges has consisted in a Joint Training Programme for networking, in an operators' network, in workshops in collaboration with other entities (ESA, CERN, XFEL, EMBL, F4E), and in an upcoming online learning platform. In particular, a Knowledge Management Strategy has been defined by EUROfusion with the purpose of minimising the loss of data and codifying tacit knowledge through four umbrella actions: capturing knowledge; building communities; improving accessibility; coordinating. Internships, open days, and extracurricular activities for teachers are organised by the European Fusion Education Network (FuseNet), an external association composed by the academia and student representatives, which receives partial support from EUROfusion. Overall, these activities mark an extensive enhancement over the previous grant agreement.

Regarding **technology transfer and the promotion of non-power applications of fusion** research, EUROfusion executes a Technology Transfer Programme with Open Calls for Demonstrators since 2022. It provides funding opportunities for recipients of EUROfusion-based technology or know-how, encouraging innovation and supporting feasibility studies for non-fusion applications. The entrepreneurs are assisted by the FUTTA III Consortium, a group of specialised brokers organised by an external consultancy (InExtenso Innovation Croissance) chosen by the EUROfusion consortium. Moreover, relevant industrial actors are engaged through EUROfusion grants for industry involvement (EUR 2,46 million in subcontracting and EUR 6,03 million in activities of the affiliated entities over 2021-2022). A dedicated framework contract for the provision of industrial expertise to EUROfusion (EUR 10.14 million in 2020-2024) with 15 specific contracts was managed by the EURATOM Research Unit to support EUROfusion in the conceptual design of DEMO and DONES. Finally, collaboration is promoted in view of the realization of a DEMO design through the Fusion Industry Innovation Forum (FIIF), consisting of 16 members from the EU industry involved in the fusion sector.

The EUROfusion Communications Office has taken up the challenge of making fusion known to the general public. It disseminates the research achievements of the partnership and coordinates the FuseCOM network among the beneficiaries' press offices. It has also provided media support to major international events like the JET campaigns and the JT60SA inauguration. It publishes the public newsletter "Fusion in Europe" and the internal newsletter "NEWSbrief". The outreach on social media has grown continuously

over the years (between +5% and +57%), while the subscriber community has increased by more than 4 times.

The staff working in EUROfusion's beneficiaries and affiliated entities consists of scientists, engineers, technicians, and administrators (see Table 9). In addition, the partnership fosters the creation of fusion-related jobs in third parties, promoting the development of expertise through grants and agreement with affiliated entities and other partners. For these numbers, major events of the last years should be considered (e.g., the exclusion of the United Kingdom from the Partnership).

Table 9. Number of EUROfusion personnel and gender balance

Year	No. of Females	No. of Males	Total	% Female
2021	871	2 589	3 460	25.17%
2022	977	3 582	4 559	21.43%
2023	893	3 218	4 111	21.72%

Source: EUROfusion