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Commission

Nuclear activities

of the Joint Research Centre

under the Seventh Framework Programme
European Atomic Energy Community (Euratom)

SUMMARY REPORT
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European Commission

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Foreword

by Vladimír Šucha, JRC Director-General

The European Atomic Energy Community (Euratom) has foreseen in its founding Treaty in 1957 a clear role for the European Union to perform direct research and disseminate its results within the Member States in order to ensure the safe use of nuclear energy and to help them meet the highest standards of safety, security and non-proliferation as well as to complement their training and education activities.

The Joint Research Centre (JRC), the European Commission's in-house science service, has been established by the Euratom Treaty and has provided both direct research and EU policy support for nuclear safety and security for over 50 years. JRC nuclear research is performed through regular multi-annual research Framework Programmes and policy support derives naturally from the expertise gained in the specific research domains.

This activity is carried out in the JRC Institutes in Geel (Institute for Reference Materials and Measurements – IRMM), Karlsruhe (Institute for Transuranium Elements – ITU) and Petten (Institute for Energy and Transport – IET), where specific nuclear infrastructure exists to perform world-class research.

The availability of the nuclear infrastructure and of its highly experienced staff has led to the JRC becoming an internationally recognised organisation in this field. This is shown by several agreements with organisations and partners such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organisation of Economic Cooperation and Development (OECD/NEA), the US Department of Energy and third countries, such as Japan, Canada, China etc.

This report describes the work that the JRC has performed within the Euratom 7th Framework Programme (2007-2013), seeking to maximise its impact within the available resources.

The report is structured around 3 main areas:

- Nuclear waste management and environmental impact
- Nuclear safety
- Nuclear safeguard and security

For each area there is a summary of the projects (called actions) that have been performed, facts and figures, action reports and thematic publications.

This report addresses all the JRC nuclear research activities during this period and I hope that it will help the reader understand the work of the JRC to provide reliable, independent and internationally recognised science to meet EU and global nuclear safety and security challenges.

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Introduction

The JRC Work Programme in Euratom FP7

The Euratom Seventh Research Framework Programme (FP7) was defined by two Council Decisions for the two periods: 2007-2011¹ and 2012-2013². Within each of these Council Decisions there were two specific programmes that were managed separately by JRC and DG RTD.

This report addresses only the activity performed by the JRC in the period covered by the two Council Decisions.

Main policy drivers behind the themes under FP7 (2007-2013)

The Euratom Treaty foresees a clear role for the EU in ensuring the safe and sustainable use of nuclear energy across Europe and supporting the Member States to meet the highest standards of nuclear safety, security and non-proliferation. The main policy drivers in the definition of the nuclear activities within FP7 were:

- the implementation of the Innovation Union
- the Energy Policy for Europe
- the European Strategic Energy Technology Plan (SET Plan)
- the Council Decision on the Community's access to the International Collaboration on Research and Development of Generation-IV International Forum
- the 7th Chapter of Euratom Treaty related to implementation of Safeguards by the EC
- Article 36 of the Euratom Treaty related to radioactivity environmental monitoring
- the support to the International Atomic Energy Agency (IAEA) for the implementation of the treaty on non-proliferation in line with the EU security strategy and the strategy related to non-proliferation of weapons of mass destruction and the EU strategy on counter-terrorism.

1. 2007-2011: COUNCIL DECISION of 18 December 2006 Concerning the Seventh Framework Programme of the European Atomic Energy Community (Euratom) for nuclear research and training activities (2007 to 2011), 2006/970/Euratom

2. 2012-2013: COUNCIL DECISION of 19 December 2011 concerning the Framework Programme of the European Atomic Energy Community for nuclear research and training activities (2012 to 2013) , (2012/93/Euratom)

Other policy drivers were linked to the implementation of the secondary Euratom legislation (recommendations, decisions and directives) and to ad-hoc Council Decisions (e.g. EU Stress Tests).

Objectives derived from policy drivers

The specific programme managed by JRC was divided in three main categories:

- (1) Nuclear waste management and environmental impact
- (2) Nuclear safety
- (3) Nuclear security

The objectives of the JRC programme were to provide customer driven scientific and technical support to the EU policy-making process in the nuclear field, ensuring support to the implementation and monitoring of existing policies while flexibly responding to new policy demands. The JRC's FP7 programme supported both European Commission and Member States in the fields of safeguards and non-proliferation, waste management, safety of nuclear installations and fuel cycle, innovation and standardisation, radioactivity in the environment and radiation protection. Within FP7, the JRC also strengthened its role as a European reference for the dissemination of information, and delivered training and education for professionals and young scientists, notably in the areas of nuclear safety and security and radiation protection.

More specifically, the JRC's nuclear activities within each category were:

1. Nuclear waste management and environmental impact: JRC research focused on reducing uncertainties associated with long-term behaviour of spent fuel and waste forms, in order to develop effective solutions for the management of high level nuclear waste. Activities were developed to:

- (a) improve processing or conditioning of long-lived waste
- (b) enhance understanding and modelling of the physics, chemistry and fundamental properties of actinide materials
- (c) contribute to a database of high accuracy nuclear reference data, for nuclear energy and non-nuclear energy applications.

In the area of radiation protection, the JRC further developed:

- (a) the European-wide environmental radioactivity monitoring systems (routine and emergency situations)
- (b) environmental models of radioisotope dispersion
- (c) monitoring tests in environmental radioactivity in support to the harmonisation of the national monitoring processes.

2. Nuclear safety: JRC research focussed on:

- (a) existing, and innovative fuel cycles e.g. safety of nuclear fuels under normal/off-normal operating conditions
- (b) nuclear materials e.g. structural materials performance and component integrity
- (c) on nuclear reactor safety of current Western/Russian nuclear Reactors and on new reactor designs e.g. operating experience feedback, severe accident scenarios.

In addition the JRC, as Euratom implementing agent, supported and coordinated the European contribution to the Generation IV International Forum R&D initiative.

3. Nuclear security: Fulfilling its EU commitments, including in particular: development of methods for the control of the fuel cycle facilities; implementation of the additional protocol including environmental sampling and integrated safeguards; and prevention of the diversion of nuclear and radioactive materials for illicit trafficking, comprising also nuclear forensics.

Major achievements in policy support

(1) Nuclear waste management and environmental impact

- Within the frame of the implementation of the new Euratom Waste Directive³, the JRC supported the Directorate-General for Energy (DG ENER), the European Nuclear Energy Forum (ENEF) and the Member States by providing information and drafting guidelines for establishing and implementing national programmes and further supported the establishing of criteria to assess the transposition of the Directive.

(2) Nuclear safety

- The JRC developed a new initiative on Nuclear Power Plants (NPPs) providing operational feedback in cooperation with the EU national nuclear safety authorities. This initiative, called 'EU Clearinghouse on Operational Experience Feedback for NPPs', organised via a network of EU regulators and their Technical Support Organizations (TSO), is operated by a centralised office located at the JRC. Within this frame, the JRC delivers support to the EU Member States by issuing topical reports on subjects important to the safe operation of EU NPPs, and published quarterly reports on worldwide NPP operational events.
- The JRC provided continuous expert support to Directorate-General for International Cooperation and Development (DG DEVCO) and the Directorate-General for Neighbourhood and Enlargement Negotiations (DG NEAR – previously DG ELARG) for the development, implementation and evaluation of more than 150 projects aimed at improving nuclear safety and radioactive waste management in countries outside the EU, in particular neighbourhood countries as well as pre-accession countries.

(3) Nuclear security

The JRC is involved in combating illicit trafficking of nuclear materials, including supporting the implementation of EU CBRN (Chemical, Biological, Radiological, Nuclear) related policies:

- Within the frame of the implementation of the EU-CBRN Action Plan, several actions were allocated to JRC which covered major areas of security concern. For example, in the field of detection, JRC supports the Directorate-General for Migration and Home Affairs (DG HOME) and the Member States in managing the Illicit Trafficking Radiation Assessment Programme (ITRAP+10) for testing equipment used for the detection of radioactive and nuclear material against international standards.
- Outside the EU, and under the Instrument contributing to Stability and Peace (former IfS), the JRC is providing extensive technical support to DG DEVCO for the implementation of the CBRN Centres of Excellence Initiative, currently counting 45 partner countries and 40 ongoing regional projects. JRC participation includes, among other tasks, performing a country by country integrated CBRN needs assessment, supporting the drafting of National Action Plans, ensuring the technical evaluation of project implementation and being responsible for the communication and visibility tools.

3. 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.

Excellent scientific results and performance

(2) Nuclear safety

- The JRC carried out irradiation tests and post-irradiation examinations of safety related fuel properties at high burn-up, and tested properties and behaviour of nuclear fuel under extreme conditions, encompassing normal and accident conditions.
 - Through its pre-normative research performed in close collaboration with standardisation bodies (International Organization for Standardization, European Committee for Standardization) and EC services (Directorate-Generals for Energy, for Research and Innovation (RTD), and for Internal Market, Industry, Entrepreneurship and SMEs (GROWTH, previously ENTR) the JRC has played a prominent role in promoting the development of codes of practice and documentary standards for various test techniques for materials qualification, in-service inspection and component design of relevance to present and future nuclear reactors.
 - The JRC performed research on physical properties of actinide elements and compounds under extreme temperatures, pressures and magnetic field conditions (for example those related to the study of the UO₂-PuO₂ phase diagram at high temperatures). An innovative experimental approach was developed to determine the accurate melting point of actinide compounds which has revealed a value more than 300 K higher for PuO₂ than earlier reported values.
 - The Fukushima accident underlined the need to better assess nuclear plant behaviour, beyond the design, under accidental conditions. In response, new activities were established in the JRC to underpin research and to build expertise (e.g. nuclear severe accident modelling, stability of molten and damaged core materials after severe accidents (addressing leaching of fission products and actinides, microstructural changes, etc.).
- Support to the International Atomic Energy Agency (IAEA) and the Organisation for Economic Co-operation and Development (OECD)/the Nuclear Energy Agency (NEA) was provided:
 - > through expert participation to IAEA Integrated Regulatory Review Service (IRRS) and IAEA Operational Safety Review Team (OSART) missions and through participation in the development of the IAEA comprehensive report on Fukushima. This work also supports DG ENER and the implementation of the EU Nuclear Safety Directive.
 - > through active participation to working groups of the OECD/NEA and which resulted in the development of several State Of the Art Reports (SOAR) in the field of accident management and operating experience for NPPs.
 - > by delivering evaluated physical data to the Joint Evaluated Fission and Fusion library.
 - The JRC continued to have a prominent role in most FP7 indirect actions relevant to the generation and management of nuclear data.

(3) Nuclear security

- In the field of security, and especially in nuclear forensics, new methods have been developed for the determination of parameters that provide clues on the origin, age and intended use of nuclear material, such as a method for rapid age determination of uranium samples.
- For the analysis of micron-sized particles from environmental samples collected by safeguards inspectors (IAEA and Euratom), a new Large Geometry Secondary Ion Mass Spectrometry (LG SIMS) laboratory has been set up (a joint JRC and DG ENER project), which combines speed (automated particle search), sensitivity and highest levels of accuracy for isotopic composition measurements.

Organisation and participation in high-visibility ad-hoc activities

(1) Nuclear waste management and environmental impact

- Upon the European Parliaments' request, the JRC organised a high level roundtable on 'Scientific support for nuclear decommissioning' which aimed to identify scientific needs, future prospects and priorities for the decommissioning of European nuclear installations.

(2) Nuclear safety

- The EU Stress Tests were requested by the European Council following the Fukushima nuclear accident. The tests were organised under the umbrella of the European Nuclear Safety Regulators Group (ENSREG). All nuclear reactors in 17 European countries were peer reviewed. In support of DG ENER, the JRC was responsible for the scientific secretariat, providing technical and administrative support throughout the whole process. Several JRC experts also participated in the peer review exercise (review of the national reports, topical reviews and country site visits) collaborating directly with EU regulatory bodies and TSO representatives. The JRC also provided experts and managed the scientific secretariat for the follow-up seminar on the stress-tests that was held in Brussels in April 2013.
- Following the request of the Council on 28 June 2011, the JRC and RTD and the European Economic and Social Committee (EESC) organised in 2013 the Symposium 'Benefits and Limitations of Nuclear Fission for a Low Carbon Economy', which addressed the research needs for a sustainable, secure, reliable and competitive energy mix, including nuclear fission and the need to strengthen the links between civil society, industry and policy makers in order to keep a sustained focus on in nuclear safety, security and safeguards.

- In support to DG RTD and ENER, the JRC has played a leading role in the design, implementation and coordination of the Joint Programme on Nuclear Materials (JPNM) set up under the umbrella of the European Energy Research Alliance (EERA) in support of the SET-Plan. Likewise, the JRC has provided support to the Nuclear Generation II & III Association) NUGENIA secretariat, and actively contributed to most of its technical areas.

(3) Nuclear security

- The second Nuclear Security Summit was held in Seoul (2012) and the third in The Hague (2014) with more than 50 countries and international organisations represented by their Heads of State (the EU was represented by President Barroso and President Van Rompuy). In both summits the JRC was the author of the main contribution of the EU to the event: the Joint Staff Working Document on 'EU efforts to strengthen nuclear security', in collaboration with relevant Commission and the European External Action Service (EEAS) services dealing with security issues.

Recognition, distinctions and honours

(1) Nuclear waste management and environmental impact

- The JRC also reported regularly on environmental radioactivity in the EU Member States and performed continuous monitoring in close collaboration with DG ENER, the Member States' National Authorities and other international organisations. The European Radiological Data Exchange Platform (EURDEP) system developed by the JRC was selected by the IAEA as technical basis for implementing the International Radiation Monitoring Information System (IRMIS).

(2) Nuclear safety

- JRC research contributed to the major reference work 'Comprehensive Nuclear Materials'⁴ published under JRC editorship and addressing the full panorama of contemporary international research in nuclear materials.

(3) Nuclear security

- In the scope of the Euratom safeguards system, the JRC developed a number of advanced technologies to support the activities of the Euratom inspectors. Due to the excellence of this work, these new technologies were adopted by the IAEA and are used for its own safeguards verification system – also known as category A equipment:
 - > COMbined Product for Uranium Concentration and Enrichment Assay (COMPUCEA)
 - > 3D Laser Range Finder (3DLR)
 - > Ultrasonic Seals
 - > 3D Laser Surface Mapping of Canister Closure Welds (LMCV)
 - > Laser Item Identification System.

4. Comprehensive Nuclear Materials, Five volume Set, Editor-in-Chief: Rudy Konings, 2012, Elsevier, ISBN: 978-0-08-056027-4

Outstanding achievements in training, education and harmonisation

General

- The JRC has developed its training program on nuclear safety, security and on waste management based on its unique infrastructure. The program includes summer schools (e.g. on actinide or decommissioning), regular courses on nuclear data, and the development of multimedia training tools.
- The JRC laboratories continued providing transnational access to their facilities for researchers from the Member States. Pre-normative research activities carried out in the state-of-the-art facilities of the JRC provide support to European standardisation through the development and implementation of relevant test standards, reference materials, and databases.

(2) Nuclear safety

- Upon request by DG ENER, the European Human Resources Observatory for the Nuclear Energy Sector (EHRO-N) was officially launched in 2011 with the JRC as operating agent in charge of its implementation and management. Since then EHRO-N has been monitoring trends in human resources and developing tools for knowledge management and preservation, including education and training workshops organised under the Enlargement and Integration Action and the implementation of the European Credit System for Vocational Education and Training in the nuclear energy field.

(3) Nuclear security

- In the field of nuclear security, the European Nuclear Security Training Centre (EUSECTRA) has been firmly established with the support of DG HOME. Its infrastructure has been upgraded to provide a dedicated facility for regular trainings. Several training sessions were organised for Member States in the field of detection, forensics and response. Similar sessions were organised as well for staff of non-EU countries.
- The JRC supports the training of IAEA inspectors related to the implementation of the additional protocol. Dedicated training sessions on different safeguards techniques and advanced methods were regularly organised by the JRC for Euratom and IAEA inspectors (e.g. on non-destructive analysis, containment and surveillance, process monitoring, high performance trace analysis and Combined Procedure for Uranium Concentration and Enrichment Assay (Compucea).
- Other well recognised programmes were the regular annual European Safeguards Research and Development Association (ESARDA) courses on nuclear safeguards and non-proliferation and specific training events in collaboration with the United States National Nuclear Security Administration (US DOE NNSA) in the field of export control.



Gelina, linear electron accelerator at JRC-IRMM in Geel, Belgium.

1. Nuclear Waste Management and environmental impact

The activities performed to achieve the FP7 indicated objectives in the field of nuclear waste management and environmental impact were organised in actions. These were:

Number	Acronym	Action Name	Action Leader	Institute
51102	NWD2	Nuclear Waste Disposal and Decommissioning	GOUDER Thomas	ITU
51201	ANFC	Alternative Nuclear Fuel Cycles	MALMBECK Rikard	ITU
51301	FPANM	Fundamental Properties of Actinides and Nuclear Materials	COLINEAU Eric	ITU
51401	ND Stds	Basic research in nuclear physics and nuclear data standards	HAMBSCH Franz-Josef	IRMM
51402	ND-MINWASTE	Nuclear data for radioactive waste management and safety of new reactor developments	PLOMPEN Arjan	IRMM
51502	AIT	Alpha-Immunotherapy	MORGENSTERN Alfred	ITU
51601	REM	Radioactivity Environmental Monitoring	DE CORT Marc	ITU
51603	RADMET	Radionuclide metrology for primary standardisation and policy support	HULT Mikael	IRMM
51604	ANTE	Analysis of Nuclear Traces in the Environment	HRNECEK Erich	ITU
51701	KTE	Knowledge Management, Training and Education	MAGILL Joseph	ITU

1.1 Summary of actions

1.1.1. 51102 (NWD2) Nuclear Waste Disposal and Decommissioning

The action, which started in the FP7 as Nuclear Waste Disposal, was reshaped in 2012 to include decommissioning research activities.

The action is focused on the identification and study of key processes relevant for safety in storage and disposal of spent nuclear fuel (irradiated U dioxide and mixed U-Pu oxide, or MOX). The main evolution of the action reflects the renewed or increased relevance of areas such as extended spent fuel storage and retrievability, handling and conditioning of damaged spent fuel, and decommissioning. Since 2012, the action includes decommissioning R&D aspects, in consideration of the ageing of the European nuclear power plant fleet and therefore the amount of radioactive waste which will arise in the coming decades.

1.1.2. 51201 (ANFC) Alternative Nuclear Fuel Cycles

The ANFC action deals mainly with an alternative strategy where the volume and the radiotoxicity of high-level waste should be significantly reduced, thus shortening the time scales needed for safe storage and associated risks. This fuel cycle strategy called Partitioning and Transmutation (P&T) includes the development of aqueous and pyrochemical processes for the separation of long-lived radionuclides and the conversion into shorter-lived or stable ones by irradiation in dedicated reactors. Research on the conditioning of high level nuclear waste has also been carried out.

1.1.3. 51301 (FPANM) Fundamental Properties of Actinides and Nuclear Materials

The aim of this action is to provide the basic and more applied knowledge to underpin the understanding of nuclear materials and fuel processes (from production of energy to waste storage), and to stand as scientific reference center of the JRC activities in the field, including knowledge dissemination. The fields of research are:

- Chemistry of actinides, providing data and analytical assistance in the synthesis and characterisation of actinide materials
- Physics of actinides, determining fundamental properties of actinide elements and compounds

- Surface science studying the physics and chemistry of surface and interfaces.
- Thermodynamics, determining high-temperature thermodynamic properties and phase diagrams of actinide materials
- Modelling, analysing basic properties of nuclear fuels, by means of first-principle calculations, and comparing them with experimental results.

1.1.4. 51401 (ND Stds) Basic research in nuclear physics and nuclear data standards

The action provides accurate neutron data for new and improved evaluated nuclear data files and for the nuclear reaction standards database, which is used in all validated nuclear data libraries, e.g. Joint Evaluated Fission and Fusion (JEFF) file and Evaluated Nuclear Data File (ENDF/B).

Neutron data standards are basic data sets in support of safe operation of nuclear reactors and the safe handling of nuclear waste. To strengthen its role as a reference nuclear data provider, the action ND Std co-operates with the Nuclear Energy Agency (NEA) databank of the Organisation for Economic Cooperation and Development (OECD), with the Nuclear Data Section of the International Atomic Energy Agency (IAEA) and other stakeholders.

1.1.5. 51402 (ND-MINWASTE) Nuclear data for radioactive waste management and safety of new reactor developments

This action is the main provider of high quality neutron data in Europe for nuclear safety applications and safety aspects of nuclear waste minimisation through recycling and transmutation of high level waste. Significantly improved nuclear data and their correlated uncertainties (covariance matrices) are used for the accurate modelling in the fields of nuclear safety and waste management and for the simulation of nuclear power installations. The cross-cutting nature of its activities make the action of relevance to Generation II, III and IV safety studies.

The action provides nuclear data to files in application libraries used by nuclear research establishments in Europe and industry (Joint Evaluated Fission and Fusion nuclear data file – JEFF, and Evaluated Nuclear Data File – ENDF/B-VII).

1.1.6. 51502 (AIT) Alpha-immunotherapy

The goal of Alpha-immunotherapy (AIT) action is the development of (non-reactor driven) methods for the production of novel alpha emitters and radionuclide generators and the provision of training and radiochemical support to hospitals to enable the safe use of alpha emitters in clinical settings.

In addition, the action is conducting pre-clinical studies and clinical trials on cancer research, in collaboration with a large number of hospitals and research centres in Europe, USA and Australia, thus contributing to the development of targeted alpha therapy, an innovative and promising method for the treatment of cancer and infectious diseases. The advantage of alpha radiation, used in this therapy, is the singularity of his physical properties, in particular high energy and short path length in human tissue, to selectively address and destroy diseased cells while sparing surrounding healthy tissue.

1.1.7. 51601 (REM) Radioactivity Environmental Monitoring

REM implements Article 39 of the Euratom Treaty. It acts as a super-national institution that neutrally collects, validates and reports radiological environmental information from EU Competent Authorities under routine and emergency conditions. The main systems being developed and operated are:

- 1) The REM data bank collecting data on the levels of radioactive contamination of the various compartments of the environment (air, water, soil).
- 2) The ECURIE (European Community Urgent Radiological Information Exchange) system is the official EC system to be used for the early notification of a nuclear accident and the subsequent rapid exchange of urgent information.
- 3) EURDEP (European Radiological Data Exchange Platform) is both a data-format for radiological data and a network for the exchange of automatic monitoring data.
- 4) ENSEMBLE (currently at IES), allows the comparison between data produced in various countries, addressing the issue of harmonisation and coherence of emergency management in relation to long range atmospheric dispersion modelling.

1.1.8. 51603 (RADMET) Radionuclide metrology for primary standardisation and policy support

The action focuses on providing decay data needed for the fields of radioactivity in the environment and radiological protection, with priorities given to radioactive waste management and nuclear medicine. The action contributes to standardising and harmonising measurements by disseminating information and providing training for professionals and young scientists. In this context, the action has established a reference centre for radioactivity measurements in the environment and food and periodically organises interlaboratory comparisons.

1.1.9. 51604 (ANTE) Analysis of Nuclear Traces in the Environment

The objectives of the ANTE action were to further develop and provide assessed methods for the analysis of traces of radioactive and nuclear materials in the environment. The action was focused on providing a better determination of the origin and sources of man-made radionuclides in the environment and a better comprehension of the mechanisms connected to their environmental impact. The action was closed in 2011 and the activities transferred mainly to 53108 NTAS.

1.1.10. 51701 (KTE) Knowledge Management, Training and Education

The action was initiated the beginning of 2007 within FP7 with the aim of contributing to the retention, maintenance and deepening of the knowledge in nuclear research. To underpin this work, this action promotes and contributes to the creation and dissemination of comprehensive sources of reliable nuclear information, such as Nucleonica.

This action supported the coordination and provision for general training needs in nuclear science and technology by scientific networking, schools and workshops and the training for young students and researchers in the nuclear field, including the use of our facilities as training platforms.

1.2 Facts and figures

The following table presents the staff and budget allocated to the projects described, to allow a comparison of their relative dimension.

Action Number	Action Name	Staff Avg/year	Operational Budget K€	Comment
51102	Nuclear Waste Disposal and Decommissioning	16	3 581	
51201	Alternative Nuclear Fuel Cycles	16	3 724	
51301	Fundamental properties of actinides and nuclear materials	25	4 966	
51401	Basic research in nuclear physics and nuclear data standards	12	2 333	
51402	Nuclear data for radioactive waste management and safety of new reactor developments	20	2 875	
51502	Alpha-Immunotherapy	8	1 615	
51601	Radioactivity environmental monitoring	6	1 582	
51602	Measurement of Radioactivity in the environment and Biological matrices	6	384	2 years duration
51603	Radionuclide metrology for primary standardisation and policy support	11	3 079	
51604	Analysis of Nuclear Traces in the Environment	3	475	3 years duration
51701	Knowledge management, Training and Education	3	511	4 years duration
	Total:	119	25 123	

1.3 Thematic area publications

The total number of books and monographs in the area of nuclear waste management and environmental impact amounts to 25, peer reviewed articles to 737 and scientific and technical reports to 213. Publications divided by task are as follows:

Action Number	Action Name	Books and Monographs	Peer reviewed articles	Scientific, technical reports
451102	Nuclear Waste Disposal and Decommissioning	6	92	52
51201	Alternative Nuclear Fuel Cycles	6	57	39
51301	Fundamental properties of actinides and nuclear materials	5	225	22
51401	Basic research in nuclear physics and nuclear data standards		65	25
51402	Nuclear data for radioactive waste management and safety of new reactor developments	1	51	29
51502	Alpha-Immunotherapy		113	6
51601	Radioactivity environmental monitoring	2	36	14
51603	Radionuclide metrology for primary standardisation and policy support		80	20
51604	Analysis of Nuclear Traces in the Environment		14	6
51701	Knowledge management, Training and Education	5	4	



Hot Cells (HC) Laboratory at JRC-ITU in Karlsruhe, Germany.

2. Nuclear Safety

The activities performed to achieve the FP7 objectives in the field of Nuclear safety were organised in actions. These were:

Number	Acronym	Action Name	Action Leader	Institute
50003	SINSAC	Support to International Nuclear Safety Activities	FARRAR Brian	IET
52103	POS <i>Closed 2011</i>	Present Nuclear Reactors - Plant Operation Safety	BRUYNOOGHE Christiane	IET
52104	NUSAC	Centralised EU Nuclear Safety Clearinghouse for Operational Experience Feedback	ZERGER Benoit	IET
52105	NURAM <i>Starts 2012</i>	Nuclear Reactor Accident Analysis and Modelling	PASCAL Ghislain	IET
52201	SNF <i>Starts 2012</i>	Safety of Nuclear Fuels and Fuel cycles	VAN UFFELEN Paul	ITU
52201	SCNF <i>Merged 2011</i>	Safety of Conventional Nuclear Fuels	WALKER Clive	ITU
52301	SANF <i>Merged 2011</i>	Safety of Advanced Nuclear Fuels	VAN UFFELEN Paul	ITU
52302	FANGS <i>Closed 2011</i>	Feasibility Assessment of Next Generation nuclear energy Systems	FUETTERER Michael	IET
52303	CAPTURE	Knowledge and Competence Management, Training and Education in Reactor design and Operation	VON ESTORFF Ulrik	IET
52304	MATTINO	MATerials performance assessment for safety and Innovative Nuclear reactOrs	NILSSON Karl-Fredrik	IET

2.1 Summary of actions

2.1.1. 50003 (SINSAC) Support to International Nuclear Safety Activities

The action started in 2013 to provide technical and scientific support to DGs ELARG and DEVCO for the implementation of the programmes and projects of the Instrument for Pre-Accession Assistance (IPA) for the countries engaged in the process of accession to the EU and the Instrument for Nuclear Safety Cooperation (INSC) for other 'third countries' worldwide. The specific activities are defined by the customer DGs on an ongoing basis.

2.1.2 52104 (NUSAC) Centralised EU Nuclear Safety Clearinghouse for Operational Experience Feedback

The NUSAC action aims at supporting the improvement of the management of Operational Experience Feedback (OEF) in the EU participating countries, by:

- strengthening cooperation between EU licensees, regulatory authorities, TSOs and the international OE community to collect, evaluate and share NPP operational events data and to apply lessons learnt.
- performing background research to support the establishment of a competence centre on OEF and nuclear safety methods and tools at the JRC.
- assessing NPP events and disseminating lessons learned to the participating countries.
- exchanging information on NPP operational events with the international OEF community.

2.1.3. 52103 (POS) Present Nuclear Reactors - Plant Operation Safety

The POS action provides research and policy support on the operation safety of existing nuclear installations, it also contributes to the fields of accident management and probabilistic safety assessment and component ageing. POS supports long-term EU policy needs on operational nuclear safety of the existing installations and optimisation of the advanced nuclear energy systems (GEN III), and provides a basis for harmonisation of European best practice and approaches regarding operational safety of nuclear installations. The action addresses the operational programmes in place for the existing nuclear installations, as well as for advanced reactors, of both Western and Eastern European designs.

2.1.4. 52302 (FANGS) Feasibility Assessment of Next Generation nuclear energy Systems

The objective of FANGS was the assessment of the evolving technical capabilities of various next generation nuclear power systems against the energy policy goals of EU countries, specifically excellent safety and low-carbon efficiency as required by the SET Plan, and also in view of European industrial competitiveness and security of energy supply. Main fields of the action were: a) feasibility and performance of reactor fuel with focus on fast reactor/transmutation fuel and high temperature reactor fuel, for which several successful irradiation tests in the HFR Petten were performed, and b) evaluation of feasibility, safety and performance of next generation nuclear reactors and fuel cycles.

2.1.5. 52304 (MATTINO) MATerials performance assessment for safety and Innovative Nuclear reactOrs

MATTINO's goal was to focus JRC's structural materials research efforts on GenIV applications. As a consequence of the Fukushima accident, to give more emphasis to severe accident, the nuclear materials related research in the Actions POS (52103) and FANGS (52302) was gathered into MATTINO. The activities performed were:

- thermo-mechanical properties, corrosion resistance, and irradiation and environmental safety performance assessment of structural materials.
- harmonisation of test methods, inspection procedures and data management tools applied in Europe for thermo-mechanical, and environmental testing;
- structural materials performance assessment under operational and accidental conditions; input to material design codes and standards;
- modelling with experimental validation of the materials performance in the respective conditions and environments.

2.1.6. 52105 (NURAM) Nuclear Reactor Accident Analysis and Modelling

The Action NURAM was created in 2012 by collecting part of the contributions of the former action POS (tasks related to severe accidents especially participation to SARNET and PHEBUS networks), and FANGS (in relation with modelling and safety assessment activities for Gen IV reactors). New projects starting in 2013, as the FP7

CESAM (Code for European Severe Accident Management) reinforced NURAM contributions to the area of severe accident and especially Severe Accident Management.

2.1.7. 52201 (SNF) Safety of Nuclear Fuels and Fuel cycles

The action Safety of Nuclear Fuels was the result of the merging of two actions in 2013: Safety of Conventional Fuels (SCNF, 52201) and Safety of Advanced Nuclear Fuels (SANF, 52301).

The SCNF action belonged to the core competences of JRC-ITU. Their objectives go from the traditional post-irradiation techniques providing information on microstructure and fission gas release to advanced techniques providing fundamental data on the thermo-physical and thermo-mechanical properties of nuclear fuel. The action is in the forefront of studies of the in-pile behaviour of nuclear fuel, studying the fragmentation of nuclear fuel during temperature transients and the high burn-up properties of a number of LWR fuel variants.

The SANF action started in FP7 as a response to the promising renaissance in nuclear energy, and to focus JRC resources to Generation IV International Forum (GIF). Fuel safety aspects of the Gen IV Gas, Sodium, and Lead (GFR,

SFR, LFR) fast reactor systems were covered investigating on safe synthesis of fuels containing minor actinides, on basic fuel properties, on fuel coolant and cladding interactions, and on irradiation behaviour. Efforts were being directed to complement the experimental work performed, with more theoretical support and to improve the scientific basis underpinning nuclear fuel behaviour.

2.1.8 52303 (CAPTURE) Knowledge and Competence Management, Training and Education in Reactor design and Operation

CAPTURE is built on three pillars:

- 1) Evaluation of Human Resources Trends in the Sustainable Energy Sector: collection of data and trend analyses on issues related to development and preservation of nuclear human resources and nuclear safety expertise in the EU.
- 2) Harmonisation and standardisation of nuclear skills recognition within the EU-27: open database taxonomy of commonly recognised nuclear skills and competences, and implementation of the ECVET system in the nuclear energy sector.
- 3) Contribution to Nuclear Education, Training and Knowledge Management: preservation of internal knowledge, contribution to nuclear training initiatives collaboration with IAEA on nuclear safety KM issues.

2.2 Facts and figures

The following table presents the staff and budget allocated to the projects described, to allow a comparison of their relative dimension.

Action Number	Action Name	Staff Avg/year	Operational Budget K€	Comment
50003	Support to International Nuclear Safety Activities			Started 2013
52103	Present Nuclear Reactors - Plant Operation Safety	7	974	5 years
52104	Centralised EU Nuclear Safety Clearinghouse for Operational Experience Feedback	9	3 032	
52105	Nuclear Reactor Accident Analysis and Modelling	9	625	2 years
52201	Safety of Conventional Nuclear Fuels (safety of nuclear fuels and fuel cycles)	25	5 080	
52301	Safety of Advanced Nuclear Fuels	13	2 274	5 years
52302	Feasibility Assessment of Next Generation nuclear energy Systems	11	2 017	5 years
52303	Knowledge and Competence Management, Training and Education in Reactor design and Operation	9	815	6 years
52304	MATerials performance assessment for safety and Innovative Nuclear reactOrs	20	3 827	5 years
	Total:	64	14 013	

2.3 Thematic area publications

The total number of books and monographs in the area of nuclear safety is 18, peer reviewed articles are 292 and scientific and technical reports are 292. Publications divided by task are as follows:

Action Number	Action Name	Books and Monographs	Peer reviewed articles	Scientific, technical reports
50003	Support to International Nuclear Safety Activities			35
52103	Present Nuclear Reactors - Plant Operation Safety	2	53	50
52104	Centralised EU Nuclear Safety Clearinghouse for Operational Experience Feedback	1	27	54
52105	Nuclear Reactor Accident Analysis and Modelling	1	30	10
52201	Safety of Conventional Nuclear Fuels (safety of nuclear fuels and fuel cycles)	12	50	53
52301	Safety of Advanced Nuclear Fuels	2	29	33
52302	Feasibility Assessment of Next Generation nuclear energy Systems		45	26
52303	Knowledge and Competence Management, Training and Education in Reactor design and Operation		17	17
52304	MAterials performance assessmenT for safety and Innovative Nuclear reactOrs		41	14



Glove boxes at JRC-ITU in Karlsruhe, Germany.

3. Nuclear Safeguards and Security

The activities performed to achieve the FP7 objectives in the field of safeguards and security were organised in actions. These were:

Number	Acronym	Action Name	Action Leader	Institute
53101	NuTraSeal	Nuclear Traceability and Sealing Systems	LITTMANN Francois	ITU
53102	METRO	Providing metrological tools to support nuclear safeguards activities	AREGBE Yetunde	IRMM
53103	FACIL	Forensics Analysis and Combating Illicit Trafficking	MAYER Klaus	ITU
53104	IANUS	Information Analysis for Nuclear Security	COJAZZI Giacomo	ITU
53105	NUVER	Nuclear Facilities Verification	SEQUEIRA Vitor	ITU
53106	NUMAMET	Nuclear Materials Measurements Techniques	BERNDT Reinhard	ITU
53108	NTAS	Nuclear and Trace Analysis for Safeguards	HEDBERG Magnus	ITU
53109	EUCBRNS	EU CBRN Security	ABOUSAHL Said	Dir A
53201	NUSIM	Nuclear Fuel Cycle Simulations	PEERANI Paolo	ITU

3.1 Summary of actions

3.1.1. 53101 (NuTraSeal) Nuclear Traceability and Sealing Systems

The SILab (Seals and Identification Laboratory) supports DG ENER and IAEA by providing prototype equipment, training, calibration and services related to development and deployment of sealing and identification equipment. It assists them also for vulnerability assessment and testing of equipment in safeguard applications. Deliverables of the action are developments to further rationalise the ultrasonic sealing concept and apply it to new applications as well as systems for medium and long term dry storage containers including seals and reading heads.

3.1.2. 53102 (METRO) Providing metrological tools to support nuclear safeguards activities

METRO supports the implementation and monitoring of EU policies in the fields of nuclear safeguards, security and safety. The action provides metrological tools, including Certified nuclear Reference Materials (CRMs) for reference measurements on nuclear material and environmental samples and interlaboratory comparisons on samples analysed in fissile material control and for environmental traces, characterised targets for measurements in nuclear physics for nuclear safety and nuclear safeguards applications. They are building up confidence in the comparability and reliability of specific measurement results on nuclear material and environmental samples.

Besides, METRO organises and supports training and education activities to alleviate the risk of the loss of nuclear knowledge for the European Union.

3.1.3 53103 (FACIL) Forensics Analysis and Combating Illicit Trafficking

The main objectives of FACIL action are:

- (1) to improve the knowledge base in nuclear forensics science
- (2) to support investigating authorities in incidents of illicit trafficking
- (3) capacity building within and outside the EU.

In support of these objectives, activities for developing, implementing and improving technical capabilities

to respond to nuclear security events such as illicit trafficking were carried out. These include the development of methods and the identification of characteristic parameters for nuclear forensics, including classical forensics on contaminated evidence. Appropriate measurement methods and data interpretation techniques are developed.

Moreover, collaboration with national authorities (such as law enforcement, regulatory bodies, radiation protection) and international organisations (e.g. International Atomic Energy Agency, the Global Initiative to Combat Nuclear Terrorism (GICNT) or the European Police Force (Europol) is given a high priority. In particular, the nuclear forensic analysis of nuclear material found out of regulatory control is provided as a service to Member State authorities.

3.1.4. 53104 (IANUS) Information Analysis for Nuclear Security

IANUS investigated the potential of open source information for deepening the understanding of ongoing nuclear security issues requiring attention and reaction by EU institutions. The action developed and used dedicated information collection and analysis tools for the acquisition and processing of the relevant open source information.

Motivated by the EU Council Regulation (EC) No 428/2009 of 5 May 2009 and amendments setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items a focus will be (i) on the identification of information and trade data sources for supporting safeguard verification activities, export controls and non-proliferation studies and (ii) on the design and development of tools to analyse these data.

IANUS provides technical information on nuclear security issues to EC services and EU stakeholders by monitoring nuclear security issues and proliferation related events. This formed the bases for producing, from open source information and technical knowledge of the nuclear fuel cycle, non-proliferation studies.

The action further contributes to the development of methodologies, software tools and methods for the evaluation of nuclear safeguards effectiveness, with



regards to proliferation resistance of existing and advanced nuclear energy systems including related fuel cycles. The action is closely connected to the Generation IV International Forum (GIF) activities.

3.1.5. 53105 (NUVER) Nuclear Facilities Verification

NUVER contributes to future Safeguards approaches and applications by doing Information and Communication Technologies (ICT) related R&D work on verification tools and techniques (for containment, surveillance, and environment modelling devices).

Guided by a vision of ICT developments, and the understanding of users' needs in the safeguards community, NUVER carries out R&D to identify and test new sensors and techniques (e.g. containment, surveillance and environment modelling devices) as well as to develop monitoring tools for the different parts of the fuel cycle, including efficient data review and information management.

The tools developed can be integrated into intelligent monitoring systems involving remote data transmission and review, which offer the possibility to detect and to timely document events through equipment that operates in unattended mode for long periods of time. Here, there are needs for tamper-proofing and data authentication that can be met by new system-design approaches. When authenticated, data from nuclear operator-owned follow-up and control systems can be directly used by safeguard authorities.

3.1.6. 53106 (NUMAMET) Nuclear Materials Measurements Techniques

This action has contributed to the strengthening of ENER (EURATOM) and IAEA inspectorates by developing and/or upgrading Non Destructive Analysis (NDA) equipment used on site, by providing direct support to the inspections, and continuous special inspectors' training.

The action manages the large experimental facility Pulsed Neutron Interrogation Test Assembly (PUNITA), whose purpose is to conduct experimental research in Non-Destructive Assay methods and instrumentation for applications in nuclear security and nuclear safeguards.

Action NUMAMET provides inspector training courses in the nuclear laboratory PERLA to EURATOM and IAEA inspectors but also to national authorities.

3.1.7. 53108 (NTAS) Nuclear and Trace Analysis for Safeguards

The NTAS action assists the Commission with its responsibilities in safeguarding the peaceful use of nuclear materials, and international cooperation for nuclear safeguards and security and support to the IAEA.

The NTAS action contributed to the nuclear material accountancy measures of DG ENER and the IAEA by providing advanced analytical measurements, operation of Euratom On-Site Laboratories at two reprocessing plants, together with wide technical support. The action provides continuous R&D and technical innovations to implement the evolving safeguards policy of present and future fuel cycles both for DG ENER and for the IAEA. The action worked at establishing increased measures to detect undeclared activities and materials using the techniques of High Performance Trace Analysis (HPTA), also called environmental sample analysis.

3.1.8. 53109 (EUCBRNS) EU CBRN Security

Inside the EU, the EU CBRNS action focused on the provision of technical support to DG HOME on the evaluation of some actions within the EU CBRN Action Plan. It also participated directly in the implementation of an important part of the CBRN Action Plan.

Outside the EU, the EUCBRNS action provides support to DG DEVCO in the implementation of the EU CBRN Risk Mitigation Centres of Excellence Initiative through technical input, analysis of CBRN needs in partner countries and regions, analysis of partner country or region project proposals, contribution to the preparation of terms of references for selected projects, contribution to ensuring quality control of executed projects in the partner countries or regions, ensuring communication between all stakeholders and contribution to the overall assistance and support to partner countries or regions. Additional important activity of the action is the coordination of CBRN security-related activities with other services of the European Commission and support to complementary actions at international level.

3.1.9. 53201 (NUSIM) Nuclear Fuel Cycle Simulations

This action has contributed to the development of methodologies, software tools and methods for nuclear security, in particular for the evaluation of nuclear safeguards effectiveness, proliferation resistance of existing and advanced nuclear energy systems including related fuel cycles and research reactors and the concept of safeguard-by-design.

NUSIM has supported the EU's nuclear security policy by focusing on detection methods and instrumentation, their evaluation, comparison and categorisation striving for harmonisation and standardisation in the field.

NUSIM develops modelling (based on Monte Carlo techniques) for safeguarding NDA instrument simulation and calibration and process monitoring in support of DG ENER and the IAEA. The Process Monitoring Laboratory

developed a software for continuous monitoring of nuclear material flow, which will be applied to study new safeguard concepts for enrichment plants. NUSIM is supporting EU nuclear security policy by focusing on detection methods and instrumentation, their evaluation, comparison and categorisation striving for harmonisation and standardisation in the field (ITRAP+10 testing campaigns for the evaluation of detection equipment, testing of innovative sensors in the frame of SCINTILLA and FLASH). Training courses are provided as contribution within EUSECTRA.

3.2 Facts and figures

This table presents the staff and budget allocated to the projects described, to allow a comparison of their relative dimension.

Action Number	Action Name	Staff Avg/year	Operational Budget K€	Comment
53101	Nuclear Traceability and Sealing Systems	7	949	
53102	Providing metrological tools to support nuclear safeguards activities	13	4 269	
53103	Forensics Analysis and Combating Illicit Trafficking	9	3 125	
53104	Information Analysis for Nuclear Security	6	1 115	
53105	Nuclear Facilities Verification	10	2 041	
53106	Nuclear Materials Measurements Techniques	8	1 774	
53108	Nuclear and Trace Analysis for Safeguards	18	3 587	
53109	EU CBRN Security			Started 2013
53201	Nuclear Fuel Cycle Simulations	14	2.348	
	Total:	84	19 208	



3.3 Thematic area publications

The total number of books and monographs in the areas of nuclear safeguards and security amounts to 10. Peer reviewed articles to 161 and scientific and technical reports to 243. Publications divided by task are as follows:

Action Number	Action Name	Books and Monographs	Peer reviewed articles	Scientific, technical reports
53101	Nuclear Traceability and Sealing Systems			14
53102	Providing metrological tools to support nuclear safeguards activities		28	10
53103	Forensics Analysis and Combating Illicit Trafficking		27	37
53104	Information Analysis for Nuclear Security	1	4	49
53105	Nuclear Facilities Verification	5	16	22
53106	Nuclear Materials Measurements Techniques	1	20	16
53108	Nuclear and Trace Analysis for Safeguards	1	16	38
53201	Nuclear Fuel Cycle Simulations	2	50	57

Nuclear activities of the Joint Research Centre Seventh Framework Programme, European Atomic Energy Community (Euratom)

European Commission
Joint Research Centre
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Abstract

This report aims to compile the information provided for the ex-post evaluation of the nuclear activities carried out by the JRC to achieve the objectives indicated in the Euratom part of the 7th Framework Programme of Research and Development. The report contains information of the activities performed during the period in the three fields: nuclear security, nuclear safety and nuclear waste disposal and environmental impact. It contains also the facts and figures of scientific productivity and of the means allocated. The report of each action contains a summary, development and history, and a description of the action: customers and stakeholders, objectives, deliverables and impacts and main highlights. Information on integration, competitive activities and training of researches is also provided.

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