# CSN 2021-2025 R&D&I Plan

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CSN CONSEJO DE SEGURIDAD NUCLEAR

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# I. Introduction

The Covid-19 pandemic has meant an important change, accelerating the transformation processes in a society that is moving towards a new paradigm in which technical and scientific knowledge will be a fundamental pillar. The Recovery, Transformation and Resilience Plan approved by the Spanish Government in April 2021 (ref. 5) sets out a new path that all public administrations shall follow in order to make significant changes in their approach and their understanding of R&D&I.

Moreover, in the longer term, the España 2050 national strategy (ref. 6) also marks a new direction in how the role of public administrations is conceived and developed, which shall be the driving force behind the innovation needed to co-create knowledge, open up to citizen participation and make the most of all the expert knowledge that is available.

Faced with the new challenges, the CSN shall conceive R&D&I as a key element for its contribution to this social and economic transformation. R&D&I activity at the CSN shall be understood as a tool that enhances the societal value of the regulatory institution's expert knowledge and is relevant for the achievement of the CSN's main objective: nuclear and radiological safety.

Spanish Law 15/1980 on the Creation of the Nuclear Safety Council (CSN, Consejo de Seguridad Nuclear) identifies one of its functions as "to establish and monitor research plans regarding nuclear safety and radiation protection". This reflects the role of research and development activities as a necessary component contributing to the CSN's compliance with the regulatory functions attributed to it.

Fulfilling this function, the R&D&I Plan is drawn up for a five-year period, the approval of which, in accordance with the CSN Statute, falls within the remit of the Plenary of this Organisation. This Plan is one of the basic elements for better fulfilment of the functions assigned to the nuclear regulator, and provides it with greater capabilities to carry out its responsibility for nuclear safety and radiation protection with excellence.

R&D&I as a dynamic element shall keep pace with any needs that may arise on the part of the regulator, which shall face increasingly complex challenges that are not alien to the CSN organisation itself, with its safety culture being the main variable. To that end, the R&D&I Plan shall adapt and seek forms of management that address — among other issues — communication with society, innovation in public administrations and climate change in its different aspects.

Innovation shall also serve to change organisational development, manage knowledge and modernise the CSN's approach, making it more open to society and seeking to create new synergies with regulated entities and with participating members of civil society. Along these lines, everything indicated in the 2020-2025 Strategic Plan is susceptible to being addressed from an innovative approach.

Furthermore, R&D&I activities play a fundamental role in ensuring the permanent updating of the technical qualifications of the CSN personnel, so that these are in keeping with the state of the art in technology and scientific knowledge and provide the solidity of the knowledge on which its activities are based.

This R&D&I Plan for the 2021-2025 period establishes the objectives of the CSN's R&D&I activities (section 2), the technical references used in its preparation (section 3) and the strategic R&D&I lines proposed by both Technical Directorates (TDs) and members of the Plenary, in support of the regulatory and institutional improvement processes (section 4 and annexes).

Section 5 of the 2021-2025 R&D&I Plan includes the basic aspects related to its management. It represents a revision of the previous one, seeking to promote R&D&I and establishing a strategy for the selection of projects which have an impact on issues relating to the functions and remit of the CSN and which can also provide support in regulatory decision-making.

In the development of this Plan, the provisions established by Spanish Royal Decree-Law 36/2020, dated December 30, which approves urgent measures for the modernisation of the Public Administration and for the execution of the Recovery, Transformation and Resilience Plan mentioned at the beginning will be taken into account, with the corresponding scope.

In view of the above, the technical content of the Plan is formulated at a sufficiently general level, in order to facilitate its validity during the five-year period foreseen. If circumstances require a substantial modification of the Plan, or if defects are found that need to be corrected, the Plan will be updated in accordance with internal regulations.

The References section includes all documents that serve as legal and technical bases for the preparation of this R&D&I Plan.

**Regulatory science**

Regulatory science could be defined as "the scientific activity carried out for the purpose of making decisions in regulation, supervision and control, especially aimed at risk management".

In nuclear safety and radiation protection, which are distinct but complementary fields when acting against radiological risk, it is essential to have regulation, as it provides:

- Increased effectiveness, i.e., ability to achieve the desired objectives or effect.
- Increased effectiveness, i.e., meaning that the regulatory system improves its ability to achieve the objective.
- Increased efficiency, i.e., better objectives are achieved with lower costs.
- It helps to bring order in contexts in which a lot of information is handled, with uncertainties, in risky contexts and with continuous discrepancies.
- It allows progress to be made transparently, so that the public can be informed about the criteria for applying the regulator before decisions are made, which shall be duly substantiated and contrasted.
- It helps to manage knowledge, since it is sometimes a matter of translating scientific experience or the results of observations into regulations, which are thus made available to society as a whole and represent small advances in radiological risk management.

**Mission and vision**

This R&D&I Plan within the CSN covers the set of activities that shall be carried out by the nuclear regulator in order to advance in terms of everything that affects the regulatory science within its remit, in compliance with its mission, vision and values as established in the current 2020-2025 Strategic Plan (ref. 4).

This Strategic Plan sets out the foundations of the CSN's Mission, Vision and Values. The "Mission" is based on its regulatory role established in the legislation. Regarding the "Vision", it mentions that it will apply the best national and international practices and promote excellence in its regulatory decisions through competence, knowledge and reliable communication. With regard to "Values", Spain's commitment to the SDGs of the 2030 Agenda is indicated, with competence and excellence, or rigour, truthfulness and reliability being other fundamental values.

R&D&I activities play a fundamental role in ensuring the permanent updating of the technical qualifications of the CSN personnel, so that these are in keeping with the state of the art in technology and scientific knowledge and provide the solidity of the knowledge on which its activities are based.

R&D&I activity at the CSN shall be understood as a tool that enhances the societal value of the regulatory institution's expert knowledge and is relevant for the achievement of the CSN's main objective: nuclear and radiological safety.

To achieve all this, it is necessary to have consolidated teams that work from public and private institutions to serve as support organisations and repositories of technical and scientific knowledge in the areas that are the responsibility of the CSN.

In order to achieve the necessary returns and ensure that R&D&I investments result in better fulfilment of the CSN's mission, several strategic challenges are posed:

- Improve the processes for allocating resources to R&D projects in order to achieve optimal use of these resources, acting in coordination with other involved entities, especially those in the public sector.
- Establishment of a strategy for the selection of R&D projects with an impact on issues relating to the functions and competences of the CSN and which may provide support for regulatory decision-making.
- Ensure the applicability of the returns obtained (following the development of R&D projects fully or partially financed by the CSN) to the functions and competences of the regulatory body.
- Promotion and participation of the CSN in the process of drawing up, developing and monitoring public R&D policies on nuclear safety and radiation protection.

In addition to these objectives aimed specifically at R&D&I, it is also important to incorporate innovation transversality in all CSN processes.

# II. Objectives of CSN R&D&I activities

The Preamble of Spanish Law 15/1980, dated April 22nd, 1980 and creating the Nuclear Safety Council, stresses the need to reinforce the effectiveness of this organisation, i.e. its capacity to achieve the highest levels of nuclear and radiological safety in all activities involving the use of ionising radiation, which shall be understood on several levels: regulatory matters, human capital, detection systems and management.

To this end, the development of regulatory capacity shall be promoted in all its elements: regulations, including prior public consultation procedures and public hearing and information, authorisation and licensing, supervision and control, coercive processes, communication, etc. With respect to human capital, the achievement of technical excellence and knowledge management (among other aspects) are fundamental. In addition, R&D&I shall address better control of all the variables that have an effect on nuclear safety and radiation protection. Finally, R&D&I activity shall contribute to the promotion of the management system, given the support it provides as an integrating instrument for internal processes related to the nuclear and radiological regulatory activity itself, as well as for processes related to quality management, information systems and economic-financial management.

R&D&I activity at the CSN shall be understood as a tool that enhances the societal value of the regulatory institution's expert knowledge and is relevant for the achievement of the CSN's main objective: nuclear and radiological safety.

Article 2 p) of Spanish Law 15/1980, dated April 22 and regarding the creation of the Spanish Nuclear Safety Council, assigns that body the following function. *"Establish and monitor research plans for nuclear safety and radiation protection"*.

This function is clearly developed in Spanish Royal Decree 1440/2010 dated November 5, which approves the Statute of the Nuclear Safety Council and wherein Article 39, *"Functions and structure of the technical directorates",* assigns it the following responsibility: *"To propose the technical standards and research projects necessary for the best performance of its functions."*

In this manner, the CSN's R&D&I activity shall focus on the needs of the CSN as a regulator, with the aim of improving its competences and its development. With this premise in mind, the TDs have defined the strategic lines of research contemplated in this R&D&I Plan. However, additional transversal lines have been opened that seek to focus on new challenges facing the CSN as a public administration and a part of a society undergoing a process of transformation.

Given that the functions of the CSN are reflected in the Process Map as operating processes, the lines of investigation have been related to one or several of the processes thus defined, (Annex I: CSN Process Map; Annex II: Strategic lines of R&D&I).

The general objectives pursued by the CSN through R&D&I activities include the following.

A. To contribute to ensuring a high level of nuclear safety, radiation protection and security at Spanish nuclear and radioactive facilities, as well as in the course of all activities involving exposure to ionising radiation.

   In this respect, R&D&I activities shall be aimed at facilitating and strengthening the regulatory activity of the CSN, as well as guaranteeing technical excellence in the areas of competence of the Council. It is, therefore, an element in the training of the regulator's technical staff and its development represents a fundamental contribution to the management of expert knowledge.

B. To improve the surveillance and control of exposure of workers, the public and the environment to ionising radiation.

   The activities corresponding to this objective include the monitoring and measurement of radiation in all phases of the life of the regulated facilities, work activities with the presence of natural radionuclides and the prevention and mitigation of the effects of abnormal operating and accident conditions at these facilities. It also includes knowledge and monitoring of the radiological quality of the environment throughout Spain and outside the area of influence of the facilities, especially in areas with existing exposures, and the long-term safety of waste management.

C. To have, when required, the technical knowledge and means necessary to assess the risks associated with facilities to be constructed in the future, as well as the operation of existing facilities under modified operating conditions.

   Fulfilment of this objective requires maintaining an adequate presence in programmes for the development of new technologies, especially those associated with facilities that are expected to be built in Spain, and improving preparation for the regulatory management of the increasing incorporation of new technologies (e.g. digital) in existing facilities. Participation in the appropriate multilateral and bilateral national and international forums, such as technological platforms and international forums, is considered fundamental.

D. To carry out innovation tasks aimed at improving the CSN's relationship with society, creating value for public use, preserving and improving the available expert knowledge and improving its dissemination.

Knowledge is interrelated, and future advances will establish fewer "closed boxes" and make more information available to society as a whole. Much more complex structures with much higher technological capabilities will be handled. Faced with this new reality, innovation sets new goals for all public administrations which shall create synergies, produce knowledge, disseminate it, and thus generate value. The Public Procurement of Innovation is an instrument included in the Spanish 2021-2027 Strategy for Science, Technology and Innovation, the purpose of which is to promote innovation from the public sector through the acquisition of innovative solutions or solutions in the development phase, which could be useful for working on new developments that are necessary to undertake the regulatory tasks of the CSN.

The Plan includes R&D&I lines derived from the powers of collaboration with the competent authorities, which article 2, heading h) of the Creating Law attributes to the CSN *"in relation to programmes for the radiological protection of persons subjected to diagnostic procedures or medical treatment with ionising radiations"*.

The R&D&I Plan shall also be a determining instrument for the implementation of the CSN's knowledge management model, as well as facilitating and developing the nuclear safety and radiation protection training strategy.

Innovation shall also serve to change organisational development, manage knowledge and modernise the CSN's approach, making it more open to society and seeking to create new synergies with regulated entities and with participating members of civil society. Along these lines, everything indicated in the 2020-2025 Strategic Plan is susceptible to being addressed from an innovative approach.

As a specific aspect to be commented on, analysis and implementation work shall be undertaken in order to comply with strategic objective 5 "To improve the perception of the regulator's activity by the public and stakeholders through rigour, truthfulness and reliability".

# III. Technical references used to develop the CSN 2021-2025 R&D&I Plan

The content of this R&D&I Plan has taken into account the experience obtained in the development of previous plans, as well as the research programmes and priorities of other organisations with objectives of common or complementary interest to those of the CSN.

## III.1. ANALYSIS OF THE DEVELOPMENT OF THE 2016-2020 R&D PLAN

In view of the development of the previous R&D Plan (2016-2020), a review of the CSN's internal processes is being carried out, so that bureaucracy is not in any case an impediment when addressing new R&D&I projects. The CSN R&D and Knowledge Management Unit, as the party responsible for the management of this Plan, is working on the search for formulas that will make it possible to be more efficient in the start-up and promotion of new lines of work.

One of the issues considered in order to propose these improvements has been the impossibility of executing a high percentage of the economic items assigned to this chapter in the CSN budgets.

Moreover, evaluations have been performed outside the CSN through the State Research Agency (AEI), which has allowed other assessments to be made available in addition to those of the CSN itself.

At international level, the participation of CSN experts in various international R&D groups has been maintained and even increased. This collaboration allows us to obtain significant returns from projects led by organisations such as the Nuclear Energy Agency of the OECD, or the Nuclear Regulatory Commission of the United States.

## III.2. R&D PROGRAMMES OF OTHER ORGANISATIONS

In accordance with the provisions of Law 14/2011, of June 1, 2011, on Science, Technology and Innovation, this R&D&I Plan is compatible with the environment described in the Spanish Science, Technology and Innovation System, whose fundamental pillars are, on the one hand, the quality of research and its scientific-technical, social and economic impact, and, on the other hand, the growing participation and leadership of companies in R&D&I activities, seeking to develop an innovative environment to respond to the great challenges of society, facilitating the acquisition of new capabilities and the incorporation of talent, reinforces Spain's leadership and international collaboration in R&D&I; and that also promotes the participation of civil society and its organisations in the said innovation process. Moreover, the guiding principles are embodied in the Spanish 2021-2023 State Plan for Scientific, Technical and Innovation Research.

One of the characteristics of R&D&I regarding nuclear safety and radiation protection is that it has a strong component of cooperation at both the national and international levels. For this reason, the activities and priorities of the R&D&I programmes of different entities have been taken into account as a fundamental aspect in the preparation of this Plan: nuclear regulatory bodies in other countries, technological entities and platforms and relevant international R&D entities in areas of interest to the CSN. In order to define the strategic technical lines of R&D which constitute the central aspect of the Plan, information from other entities has been analysed.

R&D activities and plans of other regulators and/or technical support organisations:

- US Nuclear Regulatory Commission (NRC, USA).
- Swedish Radiation Safety Authority (SSM, Sweden).
- Institut de Radioprotection et de Sûreté Nucléaire (IRSN, France).

R&D activities of relevant international public and private entities in nuclear and radiological R&D:

- Electric Power Research Institute (EPRI, USA).
- National Nuclear Laboratory (NNL, UK).
- Japan Atomic Energy Agency (JAEA, Japan).
- National Institute of Health (NIH, USA).

Strategic R&D agendas of various technological and scientific platforms:

- European Platform for Low Dose Effects Research (MELODI).
- European Platform for Radioecology (ALLIANCE).
- European Radiation Dosimetry Group (EURADOS).
- European Platform for Research into Radiological and Nuclear Emergencies (NERIS).
- European Alliance for Medical Radiation Protection Research (EURAMED).
- European Platform for Social and Human Activities linked to Radiation (SHARE).
- Joint European Program for the Integration of Radiation Protection Research (EJP-CONCERT).
- Sustainable Nuclear Energy European Platform (SNETP).

- Spanish Fission Energy Technology Platform (CEIDEN).
- Spanish Platform for Radiological Protection Research (PEPRI).

International Entities:

- Nuclear Energy Agency (NEA).
- International Atomic Energy Agency (IAEA).
- European Union (EU) In particular, the 2021-2025 Euratom research and training programme.

## III.3. ACTIVITIES RESULTING FROM THE FUKUSHIMA ACCIDENT

The previous 2016/2020 R&D Plan was, unsurprisingly, heavily marked by the impact of the accident at the Fukushima Dai-ichi power plant on the activities of the regulatory agencies — in particular the lessons learned from it, the new requirements issued as a consequence and the R&D needs that all this raised. Today, these aspects have already been integrated to some extent into the normal activities of regulatory agencies and the nuclear industry in general. In the coming years, some R&D activities in the nuclear sector will continue to be linked to the consequences of the Fukushima accident. The NEA (SAREF Group) continues to work closely with the main Japanese entities involved in nuclear regulation and R&D with regard to various R&D&I opportunities that opened up after this accident, in particular those linked to the activities that will take place in the coming decades surrounding the decommissioning of the facility affected by the accident.

# IV. Research and development programs

The Plan includes the lines of research that have been considered strategic with respect to the objectives that have been defined and that constitute the reference framework for the CSN's R&D&I activities during the term of the Plan. Within each line of research, the specific areas of research that develop them are defined.

An appendix to the Plan includes tables with a summary list of the strategic lines and areas of research ordered in accordance with the different processes developed by the CSN in its Management System.

## IV.1. STRATEGIC LINES OF R&D&I WITH RETURNS FOR NUCLEAR SAFETY

### IV.1.1. Analysis and simulation methods and tools. Fire simulation codes

This area has been developed at the CSN since its inception. The evolution of the codes used in safety analysis allows increasingly precise and detailed analyses, integrating thermal-hydraulic and neutronic aspects with structural aspects or fuel rod behaviour, and identifying different scenarios.

The following research areas are included in this line:

- Experimental thermal-hydraulic programmes, verification/validation and development of simulation tools.
- Development of MELCOR models to support Level 1 and Level 2 PSAs.
- Use of CFD (Computational Fluid Dynamics) codes, in accordance with the current international trend.
- Validation of fuel burn-up calculation codes. Improved nuclear data libraries in the new higher burn-up ranges.
- Methods and tools for severe accident analysis and simulation.
- Fire simulation techniques and codes for various scenarios and different fire sources (FDS / Fire Dynamics Simulator computational fluid dynamics models).

The regulator's use of calculation codes for safety analysis requires appropriate technical capability, including in some cases in-house calculation capability. For this reason, the CSN shall continue to maintain an active presence in research at the international level, adding such developments as may be necessary at the national level for the specific application of the results to Spanish nuclear power plants.

All of this is applicable in the field of thermohydraulics, both at power and at standstill, where modelling and validation of very local or highly complex phenomena are still required. Therefore, participation in experimental projects (generally of an international nature) which provide the information and capabilities necessary for this validation shall be continued.

The use of CFD (Computational Fluid Dynamics) codes is a growing trend, used both to resolve defects in current tools and to expand the available operating margins to address the possible decrease in operating margins caused by plant ageing or design modifications. For this reason, it is considered necessary to follow the evolution of its development. In both the general field of thermohydraulics and the particular field of CFD codes, the aim is to maintain the resources that allow the optimisation of the applications of these calculation codes, both in the CSN itself and in national research centres, universities *and* companies.

In recent years, a major effort has been made to develop simulation methods related to fire propagation. The work that has been carried out on the use and validation of reliable modelling tools for fire growth and spread, as well as smoke and heat propagation, shall be continued in order to improve the predictive capabilities of the consequences of a fire in a nuclear facility, so that new and more complex realistic scenarios, including those originating outside the facility, can be addressed.

### IV.1.2. Safety assessment methodologies

The following are suggested as priority research areas in this field:

- Development and validation of realistic security analysis methodologies. Techniques for quantifying safety margins and their uncertainties, combining probabilistic and deterministic methods.
- Development of new capabilities and updating of PSA models, as well as new PSA developments (other modes, fires, floods, etc.)
- Human and organisational factors: Update on human reliability analysis in PSAs.
- Human behaviour and human and organisational factors, under accidental conditions.
- Risk-informed management. Probabilistic safety analysis applications.

- Development of improvements in the analysis tools for PSA level 2 and calculation of uncertainties for the assessment of findings and precursor analysis.
- Development of standardised PSA model quantification tools (OpenPSA, XFTA)
- Development of methods and tools for reporting PSA outcomes and risk.

The evolution of safety analysis methodologies towards ever-greater realism, such as those that have already been evaluated at the CSN, will continue to be applied, each time targeting new safety variables. The use of realistic or "best estimate" codes in licensing activities requires the development of complex uncertainty analysis techniques. At present, one of the lines of international R&D&I is focused on the development of these methodologies and their validation, for which reason the CSN's participation in these activities shall be maintained.

The methodologies for quantifying the safety margin and its uncertainty, which combine probabilistic and deterministic methods, are currently under full development thanks to international R&D&I activities in which the CSN has been collaborating in an outstanding manner, and in which it shall continue to participate.

The implementation of the new PSA developments, which include other modes of operation, fire and flood, etc., imply new methodologies and the consideration of other phenomenologies that are being taken into account in the regulatory process. Likewise, participation in experimental projects helps to deepen the knowledge of the phenomenology of different types of fires considered in probabilistic fire analysis (e.g., high energy electric arcs).

Regarding human factors, actions have been initiated to better consider this variable in the PSAs and to better understand the organisational and cultural effects on the safety of nuclear facilities.

None of these areas can be excluded from the rapid developments linked to artificial intelligence and other technological innovations. It is to be expected that the increased capabilities in terms of computation and analysis of complex variables will bring benefits and improve the results obtained to date.

### IV.1.3. Operation, storage and transportation of fuel and spent fuel management

The following areas of research are indicated:

- Behaviour of nuclear fuel in the different operating modes (normal, transient and accidents) and, in particular, that of fuel subjected to high burn-up.
- Safety conditions for dry storage (short and long term) and transport of irradiated fuel. Mechanical behaviour of irradiated sheath materials from fuel subjected to high burn-up (hydrogen behaviour).
- Follow-up of international research for deep geological storage.
- Application of new technologies in the definition and analysis of the geological variables to be considered in the selection and control of nuclear sites.
- Development of research and innovation in the improvement of nuclear fuels. Design of advanced fuels.
- Development of improvements that make it possible to maintain the properties of the fuel elements when they have higher burn-ups and/or higher enrichments.
- Development of accident-resistant fuels.

Research into nuclear fuel at the CSN shall continue along the R&D&I lines initiated in the last decade, focused on understanding the behaviour of high burn-up fuel under different plant operating conditions and on gaining in-depth knowledge of the appropriate conditions for dry storage and transport of irradiated fuel.

To this end, participation in international projects concerning fuel behaviour under accident conditions — particularly those concerning reactivity insertion accident scenarios (NEA's CABRI and JAEA's ALPS projects) and coolant loss accident scenarios (NEA's SCIP project) — is expected to continue. As has been done to date, national collaborations in this field will also be sought in order to extract the greatest possible technical return from these projects.

We are currently participating in national and international projects that deepen our understanding of the role that hydrogen plays in the mechanical behaviour of irradiated sheath materials, both during reactor operation and in subsequent storage and transport conditions, and we will encourage collaboration and information exchange with other regulatory agencies in this field.

Research programmes concerning long-term dry storage of irradiated fuel will be of particular importance in the coming years. The CSN will continue to monitor and participate in industry initiatives (USDOE, EPRI), regulatory bodies and/or technical support organisations (USNRC, GRS) and international organisations (NEA, IAEA). At the national level, the CSN shall act as a promoter of this knowledge, involving itself from the outset in the generation of regulations and in the progress made towards definitive solutions for the geological disposal of highly radioactive wastes.

In this field, the increasing availability of advanced, low-cost and small-sized sensors without the need for wiring, which may allow monitoring and controlling storage phenomena and variables in a much more precise manner than at present, may be very relevant. The application of artificial intelligence, *big data* and new technological developments shall also be considered when defining geological and hydrogeological models, and advancing in the knowledge of the very long-term evolution of the different variables involved. All these new technologies, which have a wide range of applications, shall have a significant impact on operation and security analysis.

The Fukushima accident demonstrated, among other things, that it is possible to improve the safety of a nuclear power plant in the event of extreme events by improving the characteristics of the fuel used. The development of new fuels that improve their physicochemical properties and safety margins is another necessary R&D&I challenge for the coming years. So-called "accident-tolerant fuel" (ATF) is already an international line of work.

### IV.1.4. Material behaviour/ageing management

As an area of research within this field, the following is considered of interest:

- Degradation mechanisms of metallic and structural materials due to exposure to high irradiation.
- Degradation mechanisms associated with stress corrosion cracking in all media.
- Uncertainties associated with the fatigue degradation mechanism taking into account the environmental factor.
- Uncertainties in the environmental qualification process for cables in accordance with applicable standards.
- Effects of irradiation and temperature on structural concrete.
- Activation of other materials by high energies (fusion reactors).

In this field, it is of interest to deepen knowledge of the degradation mechanisms of metallic and structural materials, such as those derived from the effects of irradiation or stress corrosion in all its forms and media. These aspects are key to defining plant life management programmes. It is necessary to continue participating in international research projects concerning these issues, proposing initiatives that allow aspects that apply directly to the situation of Spanish plants to be addressed.

The fatigue of materials produced by the alternating thermal and mechanical stresses to which they are exposed is a widely known ageing phenomenon; it is desirable to analyse it and consider it in the design of equipment. However, multiple fatigue tests carried out in simulated operating conditions of LWR-type reactors have shown that the fatigue resistance of a material in an aqueous medium is lower than that obtained in air, which is the condition in which the fatigue evaluation was performed during the design of the primary circuit pressure boundary components according to the ASME III code. However, the conservatisms introduced in the original calculations can encompass the effect of the environment on the fatigue resistance of materials over the design life of the plant. However, it could be an important factor in long-term operation extensions, so it is considered necessary to analyse the effects of the environment on the fatigue behaviour of the affected materials and the definition of calculation methodologies that make it possible to estimate the additional operation time with guarantees of the integrity of such components exposed to this mechanism.

As a result of several international research programmes concerning cable ageing and environmental qualification, it has become clear that there are a number of aspects (uncertainties) of cable environmental qualification processes that cast doubt on the validity of the qualified service life obtained based on them. As a result, several research programmes have been launched at international level to investigate the behaviour of cable insulation polymers and research into *condition monitoring* techniques, mainly with a view to the long-term operation (LTO) of power plants. In Spain, a project has been initiated to investigate condition monitoring techniques for power cables based on tests that attempt to limit the effect of the uncertainties indicated above with a view to LTO.

The effects of irradiation and temperature on the concrete structures of nuclear power plants have been studied at the laboratory level, but not at the level of real structures subjected to these conditions. The promotion of and participation in R&D&I projects in which these structures are tested, as in the case of the José Cabrera Nuclear Power Plant, will make it possible to determine such effects with less uncertainty and to design more realistic management programmes.

The licensing of the large IFMIF-DONES facility in Granada (Spain) requires a series of investigations and developments to guarantee its correct operation from the point of view of safety and radiological protection. In particular, it is essential to verify aspects that are not well known because they have not yet been put into practice. The presence of tritium in the various systems of the facility — especially in the lithium flow or the activation of materials via high-energy neutrons — is an important aspect to take into account.

#### IV.1.5. Performance against conditions beyond the design basis (including severe accidents)

The following areas of research have been proposed:

- Robustness of electrical systems in the event of accidental situations not foreseen in their design.
- Risks derived from external hazards (earthquakes and tornadoes).
- Experimental programmes concerning severe accident issues (promoted by NEA's CSNI). Continue research related to severe accidents and severe accident phenomenology.
- Development and application of uncertainty calculation methodologies to the progression of a severe accident and its impact on the source term analysis.

Research related to severe accidents has been carried out uninterruptedly since the beginnings of the CSN, together with the Spanish organisations that have worked in this field.

This research effort needs to be maintained in order to continue with developments linked to the phenomenology involved, with scenarios that evaluate the coolability of the molten core, the chemistry of fission products and their behaviour in the primary and containment, hydrogen accumulation and deflagration, the behaviour of the containment systems, and other matters. The lessons learned from the Fukushima accident help to highlight this situation, and the results obtained will help to update the technical bases of the Severe Accident Management Guidelines and their relationship with the Emergency Operating Procedures, as well as the possible implementation of new mitigation systems or the improvement of the existing ones.

In the wake of the Fukushima accident, a new line of research has also been opened, aimed at understanding the behaviour of fuel pools under severe accident conditions, and improving the associated monitoring instrumentation required. Work may be carried out to assess the damage to the stored fuel under different

accident scenarios, the progression of the accident and to determine its consequences, in particular the associated source term.

The evidence provided by the Fukushima-Daichii accident forces us to consider the need to reassess the importance of extreme external risks. In this area, it will be necessary to review the methods for characterising risks due to earthquakes, floods, strong winds, tornadoes and other similar events, as well as to develop advanced analysis methodologies for determining the effects of each of these possible events on the structures and systems of nuclear facilities. R&D&I activities have already been initiated regarding these issues, promoted both by industry and by other regulatory bodies or international institutions, and the CSN is required to monitor and analyse the advisability of its participation.

All these severe accident analyses shall incorporate uncertainties related to the capacity and availability of the equipment, as well as uncertainties regarding the performance times of the equipment and phenomenological parameters. They shall also be translated to the external source term and to the radiological consequences.

This strategic line is related to 4.2.10 Radiation Protection (Emergency Management).

### IV.1.6. Safety in socio-technical systems (technology, people and organisations)

The following has been identified as a priority research area:

- Influence of socio-technical systems on safety. Impact of licensee organisation and management on the safety of nuclear facilities.

In the field of human reliability and the impact of organisations on safety, it is necessary to continue with the development of advanced models for calculating the probability of failure of human actions in maintenance and control room operation tasks, as well as the incorporation of organisational models. With this development, the relative importance of the technological context on failures will hopefully be more effectively assessed.

### IV.1.7. Operational experience: Databases

The following research areas may be highlighted in this area:

- Database development and collaboration in fire experience analysis.
- Use and development of international databases.

- Methods and tools to support operational experience analysis.
- Investigation of relevant incidents.
- Application of artificial intelligence in operational experience research.

In this field, the aim is to exchange information on operating experience with other nuclear regulators and institutions involved, so that this experience can be applied to the work being done in Spain. Access to the information contained in databases is fundamental and requires a high degree of detail to be used for statistical purposes. Moreover, it is essential to develop systematic methods of analysis that allow independent and reliable assessments of the consequences of the events that have occurred involving the world's collective nuclear devices and their application to risk analysis methods.

#### IV.1.8. Emergency support methods and tools (analysis, diagnosis and prognosis of emergency situations)

The following areas of research have been considered:

- Use of PSAs as an aid for emergency follow-up.
- Promoting the use of dynamic PSAs for the consideration and analysis of possible scenarios.
- Application of supercomputing in R&D linked to nuclear or radiological emergencies.

The PSA has served as a tool to determine the vulnerabilities of the design and the frequency of damage to the core under certain previously analysed scenarios. Its use in decision-making during emergencies can be a useful tool for identifying the best options.

This strategic line is related to 4.2.10 Radiation Protection (Emergency Management).

#### IV.1.9. External risk management

Studies are currently underway to improve knowledge of capable faults in the surroundings of nuclear sites, in order to be able to apply these results to seismic IPEEEs *(Individual Plant Examinations for External Events*).

Moreover, tornado risk studies should be reconsidered in order to update expert knowledge and its application in the different regulatory processes.

The following are considered to be research areas:

- Seismic risk analysis at nuclear sites.
- Analysis of tornado risks at nuclear sites.

## IV.2. STRATEGIC LINES OF R&D&I WITH RETURNS FOR RADIOLOGICAL PROTECTION

### IV.2.1. Detection and measurement: metrology and dosimetry

The following areas of research have been proposed:

- Internal dosimetry: updating of capabilities related to the techniques already available (dosimetry via bioassays, etc.)
- External dosimetry: incorporation of new developments and technologies (e.g. OSL dosimetry, electronic dosimetry, teledosimetry, etc.) and improvement of neutron dosimetry techniques.
- Metrology of special radiation fields.

It is considered necessary to maintain the capabilities of the system in this area, improving specific aspects related to both internal and external dosimetry through the incorporation of new developments and technologies, such as OSL dosimetry, electronic dosimetry, teledosimetry and other improved techniques. It is also important to update capabilities related to techniques already available, such as dosimetry via bioassays and others already developed.

In addition, in new applications such as ultra-intense LASER pulsed fields, proton therapy, etc., it is desirable to improve the current radiation measurement systems.

### IV.2.2. Risk prevention in situations of planned exposure (occupational risk prevention)

The following has been identified as a priority research area:

- Studies aimed at guaranteeing the application of the new lens dose limits in workers in all types of facilities and jobs involving risks.

This activity is aimed at facilitating the implementation of the new Directive 2013/59/EURATOM, laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. In particular, strategies shall be developed to ensure effective enforcement of this new dose limit for exposed workers.

### IV.2.3. Assessment of the radiological impact on the public and the environment. Radioecology

The following areas of research have been highlighted:

- Fukushima: R&D&I activities related to radiological protection measures for mitigation and recovery actions, and radiological impact assessment. (See 4.2.9).
- Development and improvement of severe accident source term calculation codes. Estimation of dose rates indoors (in the different cubicles or zones) and outdoors (related to Fukushima).
- Collection and analysis of experimental data to enable the development and validation of models contained in severe accident calculation codes.
- Study of relevant processes and parameters of radionuclide transfer, exposure and radiation effects.
- Integration of human and environmental protection.
- Quantification of key processes in radionuclide transfers to determine exposure to radioactive contamination of humans and non-human species.
- Quantitative determination of the ecological consequences under realistic conditions of exposure of organisms.
- Improve radiological protection of biota by integrating human and environmental protection systems into decision support processes, including ICRP and IAEA recommendations on these matters.
- Implementation of an environmental radiological protection system.

The radiological consequences of the Fukushima plant accident have given rise to different R&D&I activities related to radiological protection measures for possible mitigation and recovery actions, and to off-site impact assessment. Furthermore, actions related to the technology necessary for the collection and analysis of experimental data that allow the development and validation of the models contained in severe accident calculation codes can be addressed, as can the study of processes and relevant parameters of radionuclide transfer, exposure and radiation effects.

In this same area, actions related to the integration of human and environmental protection can be promoted.

### IV.2.4. Dismantling of facilities and site restoration

The following have been identified as areas for development within this field:

- Rehabilitation and restoration of contaminated land and areas.
- Characterisation of physical-chemical and radiological parameters of soils, with a focus on the dismantling of nuclear facilities.
- Release of sites from regulatory control.
- Management of effluents generated during site dismantling or rehabilitation activities.

This area includes the optimisation of the decommissioning processes of the facilities, as well as measurement techniques and radiological characterisation methods with a view to the rehabilitation of contaminated areas. In this same area, actions related to the control of exposure from sites where nuclear or radioactive facilities have been operating can be promoted.

### IV.2.5. Natural radiation. Existing exposure situations

The following areas of research within this field of natural radiation have been indicated:

- Map of radon potential in Spain in karst areas.
- Exhalation of radon from building materials. Radiological impact and corrective measures.
- Application of ICRP recommendation 137-part 3 to radon dose assessment in workplaces with extreme conditions.
- Public perception of radon in Spain
- NORM (Naturally Occurring Radioactive Materials) Industries: development of solutions for conventional NORM waste management.
- Risk assessment of closed or abandoned extractive industry tailings facilities
- Characterisation and remediation of contaminated land.
- NORM waste management

Areas of research that should be highlighted include the map of radon potential in Spain in karstic areas and radon exhalation from construction materials, with their radiological impact and corrective measures.

The risk of radon inhalation will be maintained as an already active work area, considering the requirements established in the new European directive that makes it mandatory to consider this risk of exposure to ionising radiation. The incidence of the new radon concentration values in homes and buildings with public access and the need to develop a radon action plan adjusted to national particularities justify further work in this area.

For industries operating with radionuclides of natural origin, the options of conducting studies on declassification of materials and development of management solutions for NORM (Naturally Occurring Radioactive Materials) waste shall be kept open.

### IV.2.6. Radiobiology

The following are some research areas in which R&D&I work is expected to be carried out: Effects of radiation doses and dose rates on carcinogenesis and other effects such as cataracts and cardiovascular disease.

The way in which the biological effects of ionising radiation are produced remains at the core of the knowledge base for carrying out radiation protection.

One of the great challenges in radiobiology is to improve knowledge of the genetic-molecular basis of the cellular response to low-dose ionising radiation exposure, in order to establish the actual associated risk more precisely and to try to identify possible differences in the response to radiation depending on individual characteristics (individual sensitivity to radiation).

Likewise, biological dosimetry, based on knowledge of the dose-response relationship of certain biomarkers, is a fundamental tool for estimating the doses that a person may have received in situations in which exposure has occurred in the absence of physical dosimetry. Therefore, it is considered desirable to continue advancing its development.

### IV.2.7. Patient radiological protection

This aspect shall be understood as supporting the CSN's entrusted function of collaborating with the health authorities in this area.

The following areas of research are noted as areas of research:

- Determination of radiation damage (see previous section). The previous section (4.2.6.) refers to the impact of radiation in general and very often at low doses. The knowledge that can be gained could be applied to patient protection, although it is not its primary purpose.

- Risk analysis through the use of risk matrices.
- Improve measurement/estimation of occupational doses in interventional radiology (related to section 4.2.2. Occupational PR).

The CSN will collaborate with the health authorities in the radiological protection of patients subjected to medical exposures. Specifically, the CSN will collaborate with the health authorities in the tasks derived from the application of the new Radiation Protection Directive, such as facilitating methods for the assessment of risk and accidents in radiotherapy and supporting the performance of studies that provide the basis for the establishment of reference levels.

In any case, the R&D&I activities addressed by the CSN in this area will be carried out within the framework of the guidelines and priorities defined by the competent authorities in this field.

### IV.2.8. Radioactive waste (very low, low and medium activity). Final storage systems

The following are the priority areas of research:

- Identification and study of non-radioactive chemical compounds and elements that may influence the behaviour of radioactive waste packages in their final disposal.
- Development of methodologies for long-term safety assessment of radioactive waste storage sites and study of radionuclide behaviour at specific storage sites.
- Indicators for the regulatory control of the processes for minimising radioactive waste generated in facilities.
- Optimisation of the calibration and commissioning processes for measuring equipment for the declassification of radioactive waste.
- Preservation of memory, knowledge and records of radioactive waste disposal sites for future generations.

It is necessary to develop methodologies for the justification and assessment of the long-term safety of radioactive waste storage facilities to facilitate the regulatory evaluation of the licensing processes of these facilities. Moreover, the need has been identified to establish indicators for the regulatory control of the waste minimisation processes to be managed and also the need to optimise the decision-making process for declassification when using measurement techniques and geometries that group together variable quantities and natures of waste materials.

In addition, an important part of the requirements is the analysis and study of the influence on storage safety of the presence of chemical components present in the waste that could affect the expected behaviour of the conditioned packages and the storage system.

In 2011, the European Nuclear Energy Agency (NEA/OECD) launched an international research initiative for the preservation of records, knowledge and memory (RK&M) concerning radioactive waste repositories. It identifies the substantial interest and need for research in this area, which shall achieve flexible and adaptable preservation processes/systems over time and be consistent with international recommendations (ICRP, IAEA) concerning the monitoring and control of radioactive waste storage over the long term. The development of these issues will facilitate their regulation and allow for the proper preservation of memory, knowledge and records after storage closure, so that future generations can make well-informed decisions about the facility and its contents and prevent inadvertent human intrusion.

### IV.2.9. Environmental radiological surveillance

Priority areas of research include the following:

- Development of rapid procedures for environmental radiological monitoring in emergencies.
- Optimisation of test methods in environmental radiological monitoring.
- Optimisation of sampling methodology in environmental radiological monitoring.
- Application of citizen science as knowledge within the control of environmental radioactivity.

In radiological or nuclear emergency situations, it is necessary to have rapid procedures for environmental radiological monitoring. The objective is to carry out early assessment of environmental contamination in different matrices (air, water, soil, food, vegetation, etc.) for proper emergency management.

The process of improving the quality system for environmental radiological monitoring is a continuous objective. The laboratories participate in various programmes to improve their capabilities in this field, such as intercomparison exercises for different types of samples. The lines of work for the improvement of environmental radiological monitoring are now being considered in relation to the optimisation of test methods, as well as sampling methodologies.

### IV.2.10. Emergency management

The following research areas are proposed as priorities:

- Monitoring strategies: development of automated remote monitoring systems for facilities and affected areas, enabling the informed use of emergency centre systems and tools.
- Improvement of nuclear emergency plans. Optimisation of protection measures based on a study of their effectiveness and the time required for their implementation, on a case-by-case basis and adapted to the actual conditions of the sites.
- Management of the post-accident recovery phase (see section 4.2.3).
- Preparation of the emergency response strategy.
- Epidemiology. Its application to nuclear post-emergency management.
- Virtual reality developments as training tools in radiological emergencies.
- Use of drones during nuclear or radiological emergency management.
- Use of new technologies in decision-making during emergencies.

Emergency management requires a series of specific methodologies and tools necessary for collecting information, evaluating it and making decisions quickly and efficiently.

Automated remote systems applicable to the monitoring and operation of systems and tools of the emergency operation centres, of the facilities themselves or of the affected areas shall also be incorporated. In general, the aim is to advance in the development of different models and tools to support decision-making.

Another area of interest is the improvement of nuclear emergency plans. The objective is to optimise protection measures by studying their effectiveness and the time required for their implementation, on a case-by-case basis and adapted to the actual site conditions. To this end, it would be necessary to develop tools to analyse the time required for evacuation at nuclear facility sites, as well as the time required to effectively implement confinement and prophylaxis and other measures that may be considered, taking into account the specific social and infrastructure context.

This strategic line is related to lines 4.1.5 (Performance against conditions beyond the design basis (including severe accidents)), and 4.1.8 (Emergency support methods and tools), both of nuclear safety.

### IV.2.11. Physical safety

The following priority areas for investigation have been identified:

- Study of new techniques for the detection of nuclear and radioactive materials, appropriate to the various conditions under which surveillance will be carried out (at borders, whether at sea, land or airports, in large mass gatherings or at major public events, etc.)
- Development of nuclear forensic techniques and analysis (applicable to the investigation of radiological crime scenes).
- Determination of the radiological vulnerability of currently operating Spanish nuclear power plants against cybercrime.
- Sociological and geostrategic analyses of possible new scenarios to be considered.
- Development of mathematical models and calculation codes for the determination of the resilience of spent fuel containers for dry storage or transport against ammunition and hollow charges.
- Development of geolocators for radioactive sources in case of theft or loss.
- Actions against drone intrusion and use of drones for surveillance and control of the environment.

This is first and foremost a matter of prevention, considering new techniques to reduce existing vulnerabilities. Moreover, the field of computer security has been opened up as an important line of action, given that nuclear facilities are critical infrastructures. In addition, it incorporates the development of techniques related to the surveillance, investigation and detection of nuclear and radioactive sources or materials in different scenarios.

### IV.2.12. Development and improvement of calculation codes related to radiation protection

The following has been indicated as a priority research area:

- Participation in prestigious international programmes in this field, including the development and improvement of calculation codes used within the scope of the CSN's remit.

The aim is to maintain the knowledge and capabilities regarding the application of calculation codes that will allow for improved evaluations in terms of RP by the nuclear regulator in areas such as shielding calculations. The aim is to be up-to-date with the necessary codes and to carry out the evaluations and inspections performed with the highest quality.

## IV.3. STRATEGIC LINES WITH CROSS-CUTTING RETURNS

### IV.3.1. Effects of climate change

The following are mentioned as preferred areas of research:

- Analysis of climate forecasts and their effects on the design variables of nuclear facilities.
- Risk of tornadoes and other extreme phenomena not contemplated.
- Effects of climate change on nuclear sites.
- Regulatory changes resulting from climate change on nuclear safety and radiation protection.
- Use of new technologies to predict extreme events with effects on nuclear facilities and radioactive waste storage facilities.

Spanish Law 7/2021, dated May 20 and concerning on climate change and energy transition, recognises the effects that the new environmental variables will have at different levels, indicates tools that will have to be contemplated, and establishes a legal framework for all the necessary development. Nuclear regulation is no stranger to this climate change and shall be adapted as necessary to meet the new risks, and to ensure that these are duly integrated in terms of nuclear safety and radiation protection.

With this new line the CSN seeks to develop projects that analyse these risks at the different facilities to be regulated, to allow the existing technical standards to be updated as appropriate, and to contribute to mitigating their effects on the different variables that influence their areas of competence.

### IV.3.2. Organisational culture. Governance, transparency and participation

The following are mentioned as preferred areas of research:

- Improvement of the safety culture at the nuclear regulator and regulated facilities.
- Public innovation in the nuclear sector.
- Development of processes to manage knowledge in the nuclear sector.
- Development and application of regulatory decision-making techniques.
- Methods for establishing regulatory acceptance limits for safety analyses.

Spanish Law 19/2013, dated December 9, regarding Transparency, Access to Public Information and Good Governance, with its implementation and subsequent developments, lays the groundwork for a new relationship between public institutions and citizens. Moreover, the CSN's Digital Transformation Plan, which is currently underway, will provide a major boost in improving access to information and citizen participation. All of this development will lead to better knowledge management and organisational culture.

All of this will require developments that may be prospective analysis, or the application of techniques such as those linked to corporate intelligence or operational research. A further option to be explored is the possibility of collaboration with other public institutions to seek innovative formulas for managing public information, or to develop open government. The aim is to adapt the CSN to the new times, in which citizens can play a more active role, receiving information and knowledge.

### IV.3.3. Agenda 2030. Sustainable development

Areas of research that have been proposed in this area include:

- Development of a methodological framework for the integrated application of the SDGs to regulator management.
- Sociological analysis of public and worker perception in the nuclear sector.
- Analysis of gender equality indicators in the selection and internal promotion within the nuclear sector.
- Improvement of management systems in the nuclear regulator. Optimisation and modernisation.
- Search for synergies with other public and private organisations with which to share experiences, resources, training, etc.
- Risk acceptability and changes in society.
- Use of artificial intelligence to explore how SDGs intervene in nuclear regulation, both in the CSN and in other regulators.
- Innovative actions to be developed within the nuclear field that address the SDGs established in the 2030 Agenda.

The 17 Sustainable Development Goals (SDGs), with their 169 goals, form the cornerstone of the new 2030 Agenda and cover the economic, social and environmental dimensions of sustainable development. In order to contribute to

these objectives, actions aimed at technological innovation are required, simultaneously seeking to achieve socio-economic and environmental sustainability within an integrated framework.

The R&D&I lines to be promoted by the CSN shall promote systems that reinforce technologies by generating tools that are useful for companies and the public. Aware that the field is very broad, this area of research is open to innovative proposals on technological systems in the nuclear and radiological fields, but it would also be of interest to generate synergies through contributions from other fields of knowledge from other branches of conventional engineering, energy, economics, entrepreneurship or politics, among others.

Technological solutions using complex network algorithms, neural networks, artificial intelligence, QSPR theories methods, etc. for the extraction of relevant information in the case of *big data* and design of predictive models.

### IV.3.4. Others to be determined

The rapid development of new technologies, such as nuclear fusion and other new components or facilities for future challenges, makes it necessary to consider future R&D&I needs in which the regulator shall be trained, and also provide knowledge and experience.

International projects are underway with experimental facilities to generate energy through nuclear fusion. This technology, although it does not have risks related to nuclear criticality, also entails the need for radiological control and supervision. The need for possible licensing in this respect opens the door to new R&D&I projects in this field.

# V. Management of the research, development and innovation Plan

There is an internal CSN Procedure that regulates this process (Ref. 9), which shall be revised in order to optimise various aspects, taking into account the experience gained during the previous period of application. Likewise, in accordance with the new objectives of this Plan, other procedures that develop some key aspects for the greater efficiency of the Plan in greater detail, such as project management, project evaluation and global monitoring of the results of R&D&I activities, will have to be reviewed. The practical application of the entire management system will, in turn, be monitored and considered in order to define possible changes or additional improvements that may arise from experience.

As a summary of the new criteria defined for the management of R&D&I activities, they focus on: strengthening the definition and use of returns (effective improvements for the CSN's regulatory work resulting from the projects); strengthening the collaborative approach and the search for synergies in the development of R&D&I activities; and strengthening and optimising information for society as a whole.

The following is a series of general considerations concerning relevant aspects to be taken into account in the management of the activities that develop the R&D&I Plan.

## V.1. COLLABORATION WITH OTHER ORGANISATIONS

The R&D&I projects in which the CSN participates are always carried out in collaboration with other organisations that share technical interests with the CSN, which has been shown to help improve the technical content of the projects and to make more efficient use of human and economic resources.

This section summarises the most important collaborations that the CSN has currently established and that shall be maintained and strengthened within the scope of this Plan.

### V.1.1. National research organisations

The CSN has been collaborating with a wide range of national entities with relevant activities in R&D&I aspects relating to nuclear safety and radiation protection. Collaboration with these entities has generally yielded satisfactory results and has the advantage that it usually allows the object of the project to be very well-adjusted to the needs of the CSN, although the aspect relating to the generation of synergies has room for improvement. Of these entities, the following should be highlighted, without prejudice to others that may arise:

- Spanish universities, a significant number of which have significant activity in R&D&I aspects relating to the functions of the CSN, have been a fundamental element for the development of projects of interest to the CSN. Throughout the previous R&D&I Plan, permanent collaboration has been maintained through lectures aimed at the creation and dissemination of knowledge related to nuclear safety and radiological protection. Throughout this R&D&I Plan, mechanisms will be established allowing this collaboration to continue. The same applies to R&D&I foundations created by universities or other public entities, such as those in the health sector.

- As regards Spanish entities specifically dedicated to R&D&I, in addition to Ciemat, which provides the CSN with technical support in different fields, there are other highly specialised entities (mostly public) that have also collaborated satisfactorily with the CSN in the past. Such is the case of Spanish National Research Council entities (e.g., the Instituto de Ciencias de la Construcción Eduardo Torroja, the Centre de Reserca en Epidemiología Ambiental, etc.), and it is to be hoped that in the future there will continue to be possibilities of collaboration for mutual benefit.

- Finally, there are other entities (public or private companies) with very diverse specificities that have also collaborated with the CSN, and with which we may expect to continue to share issues of common interest in the future, paying due attention to the peculiarities that collaboration with them may have.

As a general criterion to be applied in future collaboration with these national entities, it would be advisable, as far as possible, to work on more collaborative projects, with a greater number of participants and therefore greater synergies. Furthermore, mechanisms for collaboration between these entities and the CSN shall continue to be established for those projects in which the CSN participates with the International Organisations indicated in the following section.

These national groups shall be encouraged and maintained to support the CSN and extend their activities to applications in real situations that are useful for regulatory activities.

### V.1.2. International organisations

One of the characteristics of R&D&I regarding nuclear safety and radiation protection is that it has a strong component of cooperation at both the national and international levels. For this reason, the activities and priorities of the

R&D&I programmes of different entities have been taken into account as a fundamental aspect in the preparation of this Plan: the nuclear regulatory bodies of other countries, technological entities and platforms, and relevant international R&D entities in areas of interest to the CSN.

In the past, and at the present time, CSN participation in international projects has represented a high percentage of the total number of agreements made during the previous CSN R&D&I Plans, and their technical importance is highly relevant, given that they usually produce many more synergies than national ones, and also tend to address issues of greater complexity due to their having a much higher budget and being more at the forefront of knowledge.

The CSN maintains a permanent link with the International Atomic Energy Agency (IAEA), which issues reference documents for all regulators and participates in different developments with countries from all continents. It is essential to maintain links with the IAEA by actively participating in the forums in which activities of interest to the CSN are carried out, among them those relating to R&D&I through the so-called collaborative projects, or CRPs to use their acronym in English.

The European Union, through various framework programmes including Horizon 2020 and the current Horizon Europe 2021-2027 R&D&I programme, seeks to transfer the Sustainable Development Goals to the different policies and countries that comprise it. The ecological, social and economic transitions that are to be promoted pose a challenge for all public institutions. As regards the EURATOM Program within this Horizon, its main objectives are the development of research and training activities to reduce the risks associated with the use of nuclear energy, the development of new safe nuclear technologies and optimal radiation protection. It is a challenge for the CSN, and for Spain in general, to obtain scientific returns from all projects financed with European funds. Special attention will have to be paid to this activity during the development of this R&D Plan, in collaboration with other entities of the Spanish nuclear sector.

Moreover, the Nuclear Energy Agency of the OECD (NEA) is the institution with which the CSN has the largest number of international agreements for the development of R&D&I projects. These are international working groups that seek to pool knowledge and capabilities in a wide range of fields, encouraging the development of new codes, improvements in design, analysis of possible causes or effects, creation of databases through the sharing of information, or work on experimental reactors, among other actions. They represent a source of knowledge for the CSN, are an instrument of active collaboration to provide other countries with information of interest, and also enable the professional relations between

experts and institutions that are essential to fulfil its mission. During the development of this R&D Plan, we will continue to actively participate in all NEA working groups and committees.

In addition to the above, the CSN has signed agreements, protocols or conventions with national organisations of other countries that perform similar functions. The most important of these are those contracted with the United States regulatory body (Nuclear Regulatory Commission — NRC), and with the French regulator (Autorité de Sécurité Nucléaire — ASN). Information and experience are regularly exchanged with these organisations, and bilateral meetings are held on a regular basis.

In addition to the general collaboration agreements between the two organisations, the NRC collaborates with the NRC to provide and participate in the improvement of advanced codes in various areas such as thermohydraulics (the CAMP programme), severe accidents (the CSARP programme) and radiological analysis codes (the RAMP programme). These programmes allow the CSN to have access to first-line codes covering these topics and to develop expert knowledge on them, and are therefore of the utmost importance. In addition, they allow the CSN to enter into collaboration agreements with other Spanish entities that can access the codes, giving considerable added value to these agreements with the NRC.

- In addition, the CSN occasionally participates in R&D&I projects promoted by other foreign entities, among which the ALPS programme of the Japanese Atomic Energy Agency (JAEA) or the "Extended Storage Collaboration Programme" (ESCP) coordinated by EPRI are worthy of mention. These occasional collaborations are also of interest.

### V.1.3. Nuclear industry, universities and hospitals

Collaboration with industry organisations, universities and hospitals, some of which maintain a relationship with the CSN as regulated parties, imposes certain limitations on the research topics that may be included in shared projects, in order to maintain the CSN's independence of judgement in potential subsequent licensing processes on these topics, as well as to prevent the CSN from contributing to developments that correspond to the industry itself. It should be noted, however, that compliance with these limitations has not been an excessive impediment in the past, as evidenced by the multitude of international R&D&I projects involving regulatory bodies, electric utilities, research centres and engineering companies where this problem did not arise.

Throughout the latest 2016/2020 R&D&I Plan, collaboration with incumbents has been limited to one-off projects that are usually (but not only) identified within the CEIDEN and PEPRI Platforms. There is a framework agreement in force with CEN Foro Nuclear on joint R&D&I activities which facilitates the establishment of R&D&I agreements, but which has not been very active in recent years except in specific cases. It could be said that activity by NPP owners related to R&D&I is currently focused almost exclusively on their participation in EPRI. It is necessary to reflect seriously on the need to return to closer collaboration with licensees concerning R&D&I matters or to take a new approach to this matter (different from the current framework agreement with CEN Foro Nuclear). The level of detail of the information related to operating experience, which is only available to the licensees, is a clear example of the need for representative and reliable information that will allow both parties to make the best and most practical use of the results of the R&D&I projects associated with the subject.

Notwithstanding the above, the joint activities with the owners of NPPs which are identified from time to time in CEIDEN, and which eventually also include other entities (such as ENRESA, ENUSA, UNESA, ENSA, Empresarios Agrupados, GNF Engineering, Tecnatom, etc.), have yielded satisfactory results and should continue to be promoted. Likewise, the R&D&I activities carried out through agreements with universities and hospitals in the field of radiological protection, which arise directly between the CSN and these entities or through PEPRI, will continue to be promoted.

In February 2020, a multilateral instrument was signed for R&D&I cooperation in a nuclear energy context between the CSN and the public entities CIEMAT, ENRESA, ENUSA and ENSA, with the goal of promoting and improving joint R&D&I contributions.

### V.1.4. Creation of knowledge networks

Many of the R&D&I projects proposed in recent years are aimed at creating networks to share experiences, seek common protocols for action, or create new knowledge in a specific area.

In this regard, permanent instruments should be established to guarantee the functioning of these communities.

## V.2. TECHNOLOGY PLATFORMS AND OTHER R&D&I FORUMS

The participation of the CSN in R&D&I Technological Platforms regarding the issues for which it is responsible is a fundamental activity when it comes to promoting collaboration and the search for synergies between different entities, something that is considered to be increasingly important and that shall be considered a fundamental objective of this Plan.

The CSN actively participates in the Fission Nuclear Energy Research Technology Platform (CEIDEN) and holds the presidency of the same. This platform has been consolidated as a very valuable instrument for CSN R&D&I activities and for the other participating entities. It provides added value in other fields indirectly related to R&D&I (such as Training and Knowledge Management). Currently, some of the most relevant projects in the CSN's R&D&I portfolio have originated in CEIDEN, which has a system in place that allows and promotes the identification of topics of common interest among the members and the definition and development, where appropriate, of the corresponding R&D&I projects.

CEIDEN's activities are focused (although not exclusively) on aspects related to nuclear safety. In addition, at the European level there are several technological platforms, both in the field of nuclear technology (SNTP) and in various scientific areas related to radiation protection. Specifically, the European project EJP-CONCERT (European Joint Programme for the Integration of Radiation Protection Research) currently includes the MELODI, ALLIANCE, EURADOS, EURAMED, SHARE and NERIS platforms.

In this regard, it should be noted that the CSN does not currently participate in the SNETP platform, and any such participation could be difficult as it could be understood that the platform has a nuclear energy support component. Some monitoring of SNETP activities is carried out through CEIDEN. Nevertheless, closer monitoring of the activities of the platform and of its associated groups (particularly NUGENIA), which include numerous issues of interest as regards the CSN's competences, should be considered in order to be able to obtain technical returns from R&D&I carried out with European funds that serve the CSN's objectives, as was already reflected in section 5.1.2.

As regards scientific platforms on different issues related to radiation protection, the CSN is aware of their developments through the PEPRI platform, and participates occasionally through agreements with other entities and with some aforementioned platforms. In general, the monitoring of the activities of the European platforms related to radiation protection may provide useful information for a better configuration and definition of the R&D&I projects that the CSN plans to carry out in these areas.

In relation to activities focused on Radiation Protection, the PEPRI technology platform, in which the CSN participates and of which it also holds the presidency, is the instrument for pooling concerns regarding the development of cooperation and the search for synergies in the development of R&D&I projects in this field.

The PEPRI platform brings together multiple research institutions, both linked to medical applications and to the industrial use or environmental control of radioactivity. It therefore plays a transversal role with various objectives, ranging from the minimisation of radioactive waste, the optimisation of medical treatment times, or a better understanding of the effects of radiation. In addition, they are also entities that shall play an active role in possible emergency situations.

This platform undertakes multiple activities alongside the Spanish Society of Radiological Protection, striving to ensure maximum diffusion of its developments and debates. Moreover, at the international level, it is linked to other European platforms and serves as a channel for transferring Spanish capabilities to projects financed by the European Union. With all this, it seeks to create synergies between the different Spanish institutions interested in this scientific contribution at the international level.

This PEPRI platform has launched projects that seek to improve the interrelation between the different institutions that shall respond in the event of an emergency with radiological implications. The need to create networks that work with duly established and reviewed protocols has also been identified. With the application of this R&D&I Plan, the CSN will attempt to respond to these needs.

As regards CSN participation in other national and international R&D&I forums, this shall be assessed on a case-by-case basis, with a view to obtaining information on the needs, trends and priorities identified by other organisations carrying out research in the field of nuclear safety and radiation protection.

## V.3. MANAGEMENT OF R&D&I PROJECTS

The legal instruments used for the management of R&D&I projects are defined in internal procedure PG.IX.01 and are: collaboration agreements and grants.

In addition, other instruments may be considered as permitted by the applicable regulatory framework.

### V.3.1. Calls for the granting of subsidies

The experience acquired in the latest calls for the granting of subsidies for R&D&I projects carried out by the CSN in 2012 and 2021 confirms the validity of this project financing instrument for meeting the technical and other objectives pursued by the CSN's research activity, with the considerations indicated in the aforementioned management procedure. The use of this tool during the period covered by this Plan is, therefore, totally open to the criteria of opportunity and convenience that, if necessary, may be decided by the Plenary and logically subject to the availability of sufficient economic resources.

In accordance with the provisions of Spanish Law 38/2003 dated 17th November, the General Law on Subsidies, the CSN has approved its Strategic Subsidies Plan 2021-2023 (ref. 11). This Plan establishes the general guidelines on which the subsidies are based, with the following objectives: (1) Promotion of scientific and technical research and innovation in all sectors seeking to improve the regulatory process; (2) Promotion and maintenance of capabilities and knowledge; (3) Outreach activities.

Moreover, the regulatory bases for the granting of aid for the performance of R&D&I projects related to the functions of the CSN have been published (ref. 12). This Resolution establishes a mechanism for the granting of subsidies for R&D&I, and successive calls for subsidies may be approved during the term of this Plan.

### V.3.2. Collaboration agreements. Selection and prioritisation of projects to be developed as part of the same

In addition to the above, there is another mechanism for the management of R&D&I projects, such as the development of collaboration agreements with other entities that may be interested in developing a specific project that has been previously identified and prioritised. In recent times, this instrument has been the main tool for the development of R&D&I projects by the CSN. In this respect, the management procedure in force contemplates criteria for the selection and prioritisation of projects that are basically coherent with the practice that has historically been followed in the R&D activities carried out by the CSN, to which special emphasis has been added regarding the search for and optimisation of the returns associated with such projects.

The R&D&I projects in which the CSN participates deal mainly with issues related to nuclear safety and radiation protection. Within the limits established by the budgetary allocations available, the selection and prioritisation of the

R&D&I projects initiated by the CSN is based on technical reasoning, essentially based on the technical returns expected from the project, the need to address the specific issue proposed and its degree of applicability to the regulatory tasks performed by the CSN.

Additionally, the impact of the project on the training and updating of technical knowledge of the CSN experts participating in it shall be assessed, as well as aspects such as: the integration of the project into the CSN's R&D&I activities as a whole, within the technical areas involved; the degree of innovation contributed by the project, and its contribution to the development of the technical capabilities of other national organisations.

### V.3.3. Evaluation and use of project results

One of the objectives of the R&D&I management procedure is the identification and exploitation of the returns (benefits for the CSN's regulatory activity resulting from R&D&I projects). This objective is fully assumed by this Plan, and a fundamental aspect of all projects generated during its lifetime will be to ensure that the returns for the CSN are adequately identified from the beginning of the projects, that they are optimised during their execution and that, following their completion, the adequate management and integration of these returns is verified in the corresponding areas (evaluations, regulations, etc.)

The procedures for managing the R&D&I Plan include activities to develop and document this aspect. The returns verification and internal evaluation reports include the specific returns resulting from each project, as analysed and considered by the experts in the final and coordination reports.

### V.3.4. External and independent advice (AEI, ANECA)

With regard to the management of this Plan, which is a revision of the previous one, the aim is to involve other public institutions with experience and strategic capabilities for the selection of projects and talent. These institutions can help to raise the level of excellence, integrate CSN's R&D&I with that of other research organisations and entities, and provide support in decision-making.

The CSN carries out calls for the granting of subsidies for R&D&I projects as a formula that complies with the principle of competitive concurrence. The State Research Agency (AEI) is responsible for the public funding of R&D&I activities in Spain. Given their experience, together with the development of instruments

that allow all variables to be considered in the selection process, they are ideally suited to advise the CSN in the process of selecting the best R&D&I projects.

Moreover, the CSN wants to maintain solvent and capable research teams in Spanish universities, for which it proposes open calls for the financing of chairs in Spanish universities that direct their objectives towards nuclear safety and radiological protection. In the selection process, the Spanish National Agency for Quality Assessment and Accreditation (ANECA) will support the CSN, as it is an entity with knowledge of the university and scientific context and which establishes principles and guidelines for the evaluation of research quality.

In addition to such support, as a reference, the provisions of Spanish Royal Decree-Law 36/2020, dated December 30, which approves urgent measures for the modernisation of the Public Administration and for the execution of the Recovery, Transformation and Resilience Plan mentioned at the beginning will be taken into account.

## V.4. COMMUNICATION AND DISSEMINATION OF PROJECT RESULTS

The dissemination of the results obtained in the R&D&I projects in which the CSN participates is one of the fundamental aspects associated with these projects, for several reasons that are explained below.

On the one hand, it is necessary to disseminate the results of each project internally to all CSN personnel potentially interested in or affected by its results. This activity is important for materialising and consolidating one of the returns that any R&D&I project shall normally provide: improvements in knowledge that, in turn, allow improvements in the technical qualification and efficiency of the CSN's technical staff.

Moreover, dissemination outside the CSN is essential in order to transfer knowledge to other potentially interested entities, to the members of the scientific community that may be affected, and to the public. This is also a major objective as it allows for the improvement of cooperation with other entities and the search for possible synergies in future activities. It also provides visibility to the CSN's R&D&I work and consolidates its position in this context, which may be very useful for the identification of new opportunities for collaboration with entities that may share some of the CSN's R&D&I objectives. Finally, from a more general perspective, R&D&I has a cross-cutting component, and although it involves knowledge specific to the nuclear or radiological field, it can also contribute value to other fields of knowledge.

In this respect, the dissemination and diffusion of R&D projects, both internally and externally, will be strengthened through the following actions:

Regarding internal dissemination

That dissemination will be focused on the following activities:

- In each project, at least at the end of the project, sessions or seminars will be organised for open dissemination and explanation of the results to any CSN personnel who are potentially interested and/or affected. These sessions will be attended, as determined, by personnel from the research entities involved and also by the technical personnel of the CSN who have coordinated and supervised the project. These sessions will also have an element of training and will therefore be included in the Training Plan.
- Within the scope of the improvement of the recently executed R&D&I management process which is linked to knowledge management, it is also planned to systematically compile the documentation and experimental data generated by all CSN R&D&I projects (not only those carried out during the term of this Plan, but also previous ones where the documentation was in many cases scattered or not very accessible) and to develop an R&D documentation platform on the intranet that will allow systematisation, location by the interested parties and access to all this documentation. This improvement is under development and is expected to be fully operational within the period covered by this Plan.

Regarding external dissemination

There are several tools in this regard that have been used, to a greater or lesser extent, for many years. These include the organisation of conferences or workshops for the dissemination of project results and/or debate on the same; editorial publications and the use of the external website for communication with external persons or entities interested in the relevant aspects of CSN R&D&I activities.

As regards conferences and seminars, the CSN's annual R&D&I Workshop is a clearly consolidated and proven tool. In recent years, the Workshop has increasingly included more strategic elements and reflection on R&D and, given the time limitations, the inclusion of the public presentation of CSN projects in the agenda of the Workshop has been reduced accordingly. Therefore, the following structure is proposed:

- The R&D Workshop programme will consider a summary of the CSN's R&D&I activities during the previous year, the strategic aspects of these activities that the CSN management wishes to transmit, and will allow

time for presentations by relevant entities that collaborate with the CSN in R&D&I issues in general and in aspects of knowledge management linked to the same (e.g., technology platforms, CSN chairs existing at different Spanish universities, etc.). It will also include one or more presentations of special relevance: invited personalities from the world of R&D&I, results of particular significance of a project, etc.

- The public dissemination of the results of specific projects will take place in thematic workshops, which may be organised as many as deemed necessary, with an agenda more focused on the technical and scientific presentation by those involved in the activities, with conclusions, etc. of the various projects that are considered to fit better with the subject in question.

The CSN will consider the possibility of preparing publications when deemed appropriate, in each case analysing the most suitable way of disseminating them.

The recordings of the workshops, including the presentations made, and any documentation provided to the participants, will be considered public as an instrument for the dissemination of knowledge.

On both a national and international scale, the publication of articles and monographs in widely distributed scientific journals or specialised journals will be promoted, together with the presentation of R&D&I projects at congresses, workshops and conferences.

At the national level, the establishment of long-term framework agreements with universities, research centres and other public and private entities that facilitate the dissemination and exchange of experimental results and data will be promoted. These framework agreements provide a suitable umbrella for the fulfilment of confidentiality agreements relating to source projects, and to facilitate the launching of specific national projects and agreements related to these results in a timely manner.

As regards the CSN website, the information currently included therein focuses more on strategic aspects (summary of the R&D&I Plan), calls for the granting of subsidies and summary information on CSN R&D&I activities (projects under way and completed), as well as links to other entities that may be of use.

# VI. References

1. Consolidated Text of Spanish Law 25/1964 dated April 29, 1964, regarding Nuclear Energy, as amended by Law 33/2007 dated November 7, and Law 11/2009 dated October 26, 2009.

2. Revised text of Spanish Law 15/1980 creating the Nuclear Safety Council, as amended by Law 33/2007.

3. Spanish Royal Decree 1440/2010 dated 5 December, approving the CSN Charter.

4. CSN 2020-2025 Strategic Plan.

5. The Government of Spain. "Recovery, Transformation and Resilience Plan" (April 27, 2021).

6. The Government of Spain. "Spain 2050. Fundamentals and Proposals for a Long-Term National Strategy" (May 2021).

7. 2016/ 2020 R&D Plan of the CSN.

8. Spanish Ministry of Science and Innovation. Spanish 2021-2023 State Plan for Scientific, Technical and Innovation Research.

9. Management Procedure PG.IX.01 "Management of the CSN R&D Plan".

10. SAREF Group Report (Senior Expert Group on Research Opportunities after the Fukushima Accident").

11. CSN Strategic Grants Plan 2021-2023. Approved at the Plenary meeting dated 19/05/2021.

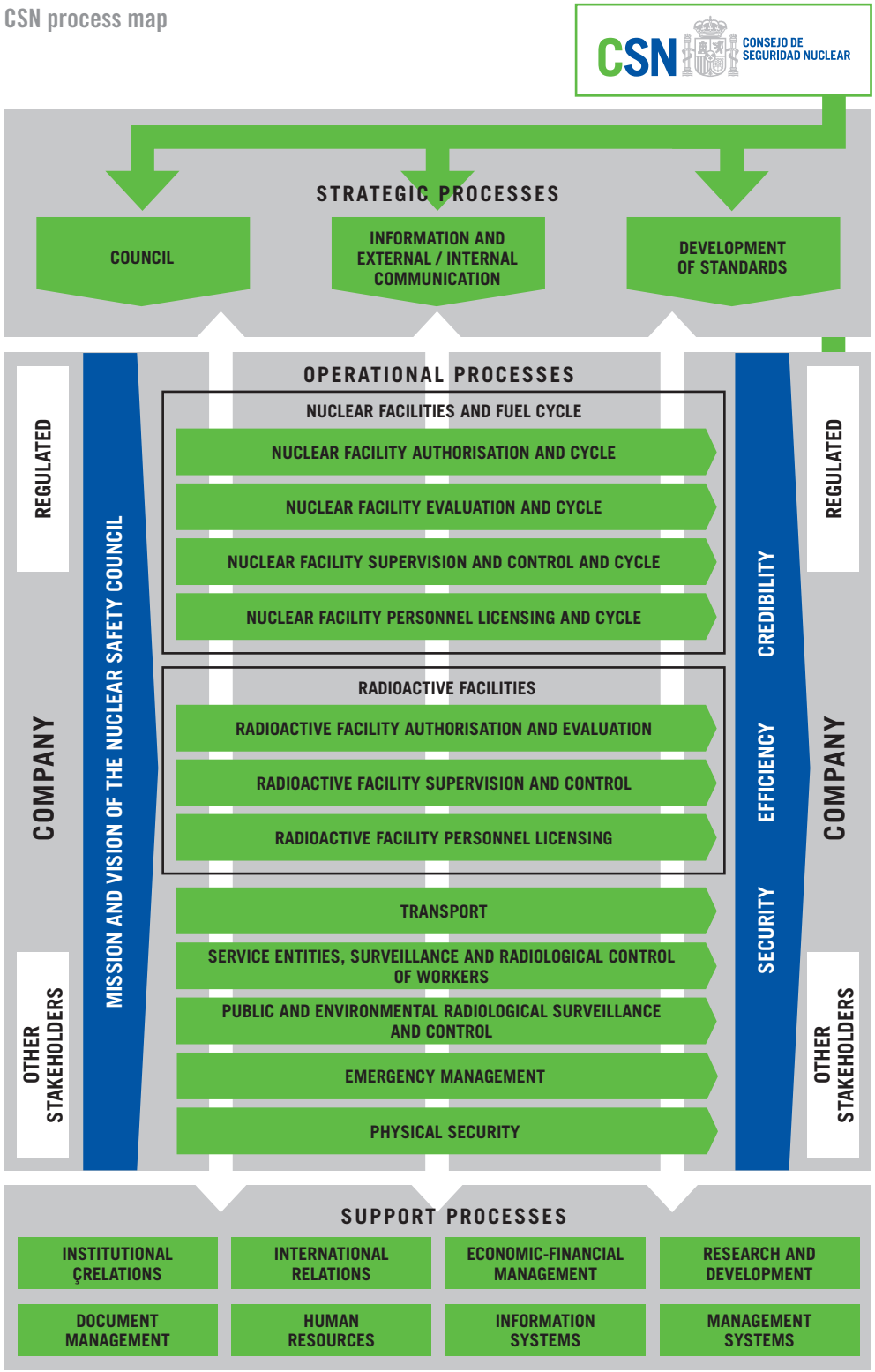
12. Resolution dated May 28, 2021, by the Nuclear Safety Council, establishing the regulatory bases for the granting of aid to carry out R&D projects related to the functions of the organisation (BOE of June 3, 2021).

13. 2021-2027 Spanish Science, Technology and Innovation Strategy. Spanish Ministry of Science and Innovation. Approved by the Council of Ministers on 8/9/2020.

# VII. Appendices

# APPENDIX I

## CSN process map



# APPENDIX II

## Table of strategic lines for csn R&D&I relating to nuclear safety, radiological protection and physical safety, including cross-cutting returns

| STRATEGIC LINES RELATING TO NUCLEAR SAFETY (section 4.1) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.1. Analysis and simulation methods and tools. Fire simulation codes. | 1.1.1. Experimental thermal-hydraulic programmes, verification/validation and development of simulation tools. |
| | | 1.1.2. Development of MELCOR models to support Level 1 and Level 2 PSAs. |
| | | 1.1.3. Use of CFD (Computational Fluid Dynamics) codes, in accordance with the current international trend. |
| | | 1.1.4. Validation of fuel burn-up calculation codes. Improved nuclear data libraries in the new higher burn-up ranges. |
| | | 1.1.5. Methods and tools for severe accident analysis and simulation. |
| | | 1.1.6. Fire simulation techniques and codes for various scenarios and different fire sources (FDS / Fire Dynamics Simulator computational fluid dynamics models). |
| | 1.2. Safety assessment methodologies. | 1.2.1. Development and validation of realistic security analysis methodologies. Techniques for quantifying safety margins and their uncertainties, combining probabilistic and deterministic methods. |

| STRATEGIC LINES RELATING TO NUCLEAR SAFETY (section 4.1) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.2. Safety assessment methodologies. | 1.2.2. Development of new capacities and updating of PSA models. |
| | | 1.2.3. Human and organisational factors: Update on human reliability analysis in PSAs. |
| | | 1.2.4. Human behaviour, and human and organisational factors, under accidental conditions. |
| | | 1.2.5. Risk-informed management. Applications of probabilistic safety analysis. |
| | | 1.2.6. Development of improvements in the analysis tools for PSA level 2 and calculation of uncertainties for the assessment of findings and precursor analysis. |
| | | 1.2.7. Development of methods and tools for reporting PSA outcomes and risk. |
| | | 1.2.8. Development of standardised PSA model quantification tools (OpenPSA, XFTA). |
| | 1.3. Operation, storage and transportation of fuel, and spent fuel management. | 1.3.1. Behaviour of nuclear fuel in the different operating modes (normal, transient and accidents) and, in particular, that of fuel subjected to high burn-up. |

| STRATEGIC LINES RELATING TO NUCLEAR SAFETY (section 4.1) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.3. Operation, storage and transportation of fuel, and spent fuel management. | 1.3.2. Safety conditions for dry storage (short and long term) and transport of irradiated fuel. Mechanical behaviour of irradiated sheath materials from fuel subjected to high burn-up (hydrogen behaviour). |
| | | 1.3.3. Follow-up of international research for deep geological storage. |
| | | 1.3.4. Application of new technologies in the definition and analysis of the geological variables to be considered in the selection and control of nuclear sites. |
| | | 1.3.5. Development of improvements that make it possible to maintain the properties of the fuel elements when they have higher burn-ups and/or higher enrichments. |
| | | 1.3.6. Development of accident-resistant fuels. |
| | | 1.3.7. Development of research and innovation in the improvement of nuclear fuels. Design of advanced fuels. |
| | 1.4. Material behaviour/ageing management. | 1.4.1. Degradation mechanisms of metallic and structural materials due to exposure to high irradiation. |
| | | 1.4.2. Degradation mechanisms associated with stress corrosion cracking in all media. |

| STRATEGIC LINES RELATING TO NUCLEAR SAFETY (section 4.1) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.4. Material behaviour/ageing management. | 1.4.3. Uncertainties associated with the fatigue degradation mechanism taking into account the environmental factor. |
| | | 1.4.4. Uncertainties in the environmental qualification process for cables in accordance with applicable standards. |
| | | 1.4.5. Effects of irradiation and temperature on structural concrete. |
| | | 1.4.6. Activation of materials by high energies (fusion process). |
| | 1.5. Performance against conditions beyond the design basis (including severe accidents). (Related to Radiation Protection Line 10) | 1.5.1. Robustness of electrical systems in the event of accidental situations not foreseen in their design. |
| | | 1.5.2. Risks derived from external hazards (earthquakes and tornadoes). |
| | | 1.5.3. Experimental programmes concerning severe accident issues (promoted by NEA's CSNI). Continue research related to severe accidents and severe accident phenomenology. |
| | | 1.5.4. Development and application of uncertainty calculation methodologies to the progression of a severe accident and its impact on the source term analysis. |

| STRATEGIC LINES RELATING TO NUCLEAR SAFETY (section 4.1) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.6. Safety in socio-technical systems (technology, people and organisations). | 1.6.1. Influence of socio-technical systems on safety. Impact of licensee organisation and management on the safety of nuclear facilities. |
| | 1.7. Operational experience: Databases. | 1.7.1. Development of databases and collaboration of fire experience analysis. |
| | | 1.7.2. Use and development of international databases. |
| | | 1.7.3. Methods and tools to support operational experience analysis. |
| | | 1.7.4. Investigation of relevant incidents. |
| | | 1.7.5. Application of artificial intelligence in operational experience research. |
| EMERGENCY MANAGEMENT | 1.8. Emergency support methods and tools (analysis, diagnosis and prognosis of emergency situations). (Related to Radiation Protection Line 10) | 1.8.1. Use of the PSAs for emergency follow-up assistance. |
| | | 1.8.2. Promoting the use of dynamic PSAs for the consideration and analysis of possible scenarios. |
| | | 1.8.3. Application of supercomputing in R&D linked to nuclear or radiological emergencies. |
| NUCLEAR FACILITY EVALUATION AND CYCLE<br><br>NUCLEAR FACILITY SUPERVISION AND CONTROL AND CYCLE | 1.9. External risk management. | 1.9.1. Seismic risk analysis at nuclear sites. |
| | | 1.9.2. Analysis of tornado risks at nuclear sites. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| SERVICE ENTITIES, SURVEILLANCE AND RADIOLOGICAL CONTROL OF WORKERS | 2.1. Detection and measurement: metrology and dosimetry. | 2.1.1. Internal dosimetry: Updating of knowledge and skills related to the techniques already available (dosimetry by bioassays, etc.). |
| | | 2.1.2. External dosimetry: incorporation of new developments and technologies (OSL dosimetry, electronic dosimetry, teledosimetry, etc.) and improvement of neutron dosimetry techniques. |
| | | 2.1.3. Metrology of special radiation fields. |
| | 2.2. Risk prevention in situations of planned exposure (occupational risk prevention). | 2.2.1. Studies aimed at guaranteeing the application of the new lens dose limits in workers in all types of facilities and jobs involving risks. Note: activity aimed at facilitating the implementation of the new Directive 2013/59/EURATOM. |
| RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT | 2.3. Assessment of the radiological impact on the public and the environment. Radioecology. | 2.3.1. Fukushima: R&D activities related to radiological protection measures for mitigation and recovery actions and radiological impact assessment. |
| | | 2.3.2. Development and improvement of severe accident source term calculation codes. Estimation of dose rates indoors (in the different cubicles or zones) and outdoors (related to Fukushima). |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT | 2.3. Assessment of the radiological impact on the public and the environment. Radioecology. | 2.3.3. Collection and analysis of experimental data to enable the development and validation of models contained in severe accident calculation codes. |
| | | 2.3.4. Study of relevant processes and parameters of radionuclide transfer, exposure and radiation effects. |
| | | 2.3.5. Integration of human and environmental protection. |
| | | 2.3.6. Quantification of key processes in radionuclide transfers to determine exposure to radioactive contamination of humans and non-human species. |
| | | 2.3.7. Quantitative determination of the ecological consequences under realistic conditions of exposure of organisms. |
| | | 2.3.8. Improve radiological protection of biota by integrating human and environmental protection systems into decision support processes, including ICRP and IAEA recommendations on these matters. |
| | | 2.3.9. Implementation of an environmental radiological protection system. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT | 2.4. Facility decommissioning. | 2.4.1. Rehabilitation and restoration of contaminated land and areas. |
| | | 2.4.2. Characterisation of physical-chemical and radiological parameters of soils, with a focus on the dismantling of nuclear facilities. |
| | | 2.4.3. Release of sites from regulatory control. |
| | | 2.4.4. Management of effluents generated during site dismantling or rehabilitation activities. |
| | 2.5. Existing exposure situations in relation to natural radiation. | 2.5.1. Map of radon potential in Spain in karst areas. |
| | | 2.5.2. Exhalation of radon from building materials. Radiological impact and corrective measures. |
| | | 2.5.3. Application of ICRP recommendation 137-part 3 to radon dose assessment in workplaces with extreme conditions. |
| | | 2.5.4. Public perception of radon in Spain. |
| | | 2.5.5. NORM (Naturally Occurring Radioactive Materials) Industries: development of solutions for conventional NORM waste management. |
| | | 2.5.6. Risk assessment of closed or abandoned extractive industry tailings facilities. |
| | | 2.5.7. Characterisation and remediation of contaminated land. |
| | | 2.5.8. NORM waste management. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| SERVICE ENTITIES, SURVEILLANCE AND RADIOLOGICAL CONTROL OF WORKERS<br>RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT | 2.6. Radiobiology. | 2.6.1. Effects of radiation doses and dose rates on carcinogenesis and other effects such as cataracts and cardiovascular disease. |
| NOT RELATED TO ANY PROCESS | 2.7. Patient radiological protection[1]. | 2.7.1. Determination of radiation damage (mentioned in the previous point). |
| | | 2.7.2. Risk analysis through the use of risk matrices. |
| | | 2.7.3. Improve measurement/estimation of occupational doses in interventional radiology (related to strategic line 2. PR in situations of planned exposure (occupational PR). |
| NUCLEAR FACILITY AUTHORISATION AND CYCLE<br>NUCLEAR FACILITY EVALUATION AND CYCLE<br>NUCLEAR FACILITY SUPERVISION AND CYCLE<br><br>RADIOACTIVE FACILITY | 2.8. Radioactive waste (very low, low and medium activity). Final storage systems. | 2.8.1. Identification and study of non-radioactive chemical compounds and elements that may influence the behaviour of radioactive waste packages in their final disposal. |

1 The inclusion of this line of research responds to the provisions of article 2, heading h) of the Law creating the CSN, which establishes "Collaborating with the competent authorities in relation to programmes for the radiological protection of persons subjected to diagnostic procedures or medical treatment with ionising radiations" as a function of the CSN.

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY AUTHORISATION AND CYCLE<br>NUCLEAR FACILITY EVALUATION AND CYCLE<br>NUCLEAR FACILITY SUPERVISION AND CYCLE<br><br>RADIOACTIVE FACILITY | 2.8. Radioactive waste (very low, low and medium activity). Final storage systems. | 2.8.2. Development of methodologies for long-term safety assessment of radioactive waste storage sites and study of radionuclide behaviour at specific storage sites. |
| | | 2.8.3. Indicators for the regulatory control of the processes for minimising radioactive waste generated in facilities. |
| | | 2.8.4. Optimisation of the calibration and commissioning processes for measuring equipment for the declassification of radioactive waste. |
| | | 2.8.5. Preservation of memory, knowledge and records of radioactive waste disposal sites for future generations. |
| RADIOACTIVE FACILITY SUPERVISION AND CONTROL<br><br>RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT | 2.9. Environmental radiological surveillance. | 2.9.1. Development of rapid procedures for environmental radiological monitoring in emergencies. |
| | | 2.9.2. Optimisation of test methods in environmental radiological monitoring. |
| | | 2.9.3. Optimisation of sampling methodology in environmental radiological monitoring. |
| | | 2.9.4. Application of citizen science as knowledge within the control of environmental radioactivity. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
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| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| EMERGENCY MANAGEMENT | 2.10. Emergency management. (Related to nuclear safety lines 1.5 and 1.8). | 2.10.1. Monitoring strategies: development of automated remote monitoring systems for facilities and affected areas, enabling the informed use of emergency centre systems and tools. |
| | | 2.10.2. Improvement of nuclear emergency plans. Optimisation of protection measures based on a study of their effectiveness and the time required for their implementation, on a case-by-case basis and adapted to the actual conditions of the sites. |
| | | 2.10.3. Management of the post-accident recovery phase (see strategic line 2.3). |
| | | 2.10.4. Preparation of the emergency response strategy. |
| | | 2.10.5. Epidemiology. Its application to nuclear post-emergency management. |
| | | 2.10.6. Virtual reality developments as training tools in radiological emergencies. |
| | | 2.10.7. Use of drones during nuclear or radiological emergency management. |
| | | 2.10.8. Use of new technologies in decision-making during emergencies. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
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| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| PHYSICAL SECURITY | 2.11. Physical safety. | 2.11.1. Study of new techniques for the detection of nuclear and radioactive materials, appropriate according to the different conditions in which it will be carried out (at borders, either maritime, land or airports, in large mass concentrations or public events of great importance, etc.). |
| | | 2.11.2. Development of nuclear forensic techniques and analysis (applicable to the investigation of radiological crime scenes). |
| | | 2.11.3. Determination of the radiological vulnerability of currently operating Spanish nuclear power plants against cybercrime. |
| | | 2.11.4. Sociological and geostrategic analyses of possible new scenarios to be considered. |
| | | 2.11.5. Development of mathematical models and calculation codes for the determination of the resilience of spent fuel containers for dry storage or transport against ammunition and hollow charges. |
| | | 2.11.6. Development of geolocators for radioactive sources in case of theft or loss. |
| | | 2.11.7. Actions against drone intrusion and use of drones for surveillance and control of the environment. |

| STRATEGIC LINES RELATING TO RADIOLOGICAL PROTECTION AND PHYSICAL SAFETY (section 4.2) | | |
|---|---|---|
| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| NUCLEAR FACILITY AUTHORISATION AND CYCLE<br>NUCLEAR FACILITY EVALUATION AND CYCLE<br>NUCLEAR FACILITY SUPERVISION AND CYCLE<br><br>SERVICE ENTITIES, SURVEILLANCE AND RADIOLOGICAL CONTROL OF WORKERS<br><br>RADIOLOGICAL SURVEILLANCE AND MONITORING OF THE PUBLIC AND THE ENVIRONMENT<br><br>EMERGENCY MANAGEMENT | 2.12. Development and improvement of calculation codes related to radiation protection. | 2.12.1. Participation in prestigious international programmes in this field, including the development and improvement of calculation codes used within the scope of the CSN's competences. |

| STRATEGIC LINES WITH CROSS-CUTTING RETURNS (section 4.3) | | |
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| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| DEVELOPMENT OF STANDARDS<br>AUTHORISATION, EVALUATION SUPERVISION AND CONTROL OF REGULATED FACILITIES | 3.1. Effects of climate change. | 3.1.1. Analysis of climate forecasts and their effects on the design variables of nuclear facilities. |
| | | 3.1.2. Risk of tornadoes and other extreme phenomena not contemplated. |
| | | 3.1.3. Effects of climate change on nuclear sites. |
| | | 3.1.4. Regulatory changes resulting from climate change on nuclear safety and radiation protection. |
| | | 3.1.5. Use of new technologies to predict extreme events with effects on nuclear facilities and radioactive waste storage facilities. |
| COUNCIL<br>RESEARCH AND DEVELOPMENT<br>INFORMATION AND INTERNAL / EXTERNAL COMMUNICATION<br>DEVELOPMENT OF STANDARDS<br>KNOWLEDGE MANAGEMENT | 3.2. Organisational culture. Governance, transparency and participation. | 3.2.1. Improvement of the safety culture at the nuclear regulator and regulated facilities. |
| | | 3.2.2. Public innovation in the nuclear sector.. |
| | | 3.2.3. Development of processes to manage knowledge in the nuclear sector. |
| | | 3.2.4. Development and application of regulatory decision-making techniques. |
| | | 3.2.5. Methods for establishing regulatory acceptance limits for safety analyses. |

| STRATEGIC LINES WITH CROSS-CUTTING RETURNS (section 4.3) | | |
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| **CSN PROCESSES** | **STRATEGIC LINES** | **RESEARCH AREAS** |
| COUNCIL RESEARCH AND DEVELOPMENT INFORMATION AND INTERNAL / EXTERNAL COMMUNICATION | 3.3. Agenda 2030. Sustainable development. | 3.3.1. Development of a methodological framework for the integrated application of the SDGs to regulator management. |
| | | 3.3.2. Sociological analysis of public and worker perception in the nuclear sector. |
| | | 3.3.3. Analysis of gender equality indicators in the selection and internal promotion within the nuclear sector. |
| | | 3.3.4. Improvement of management systems in the nuclear regulator. Optimisation and modernisation. |
| | | 3.3.5. Search for synergies with other public and private organisations with which to share experiences, resources, training, etc. |
| | | 3.3.6. Risk acceptability and changes in society. |
| | | 3.3.7. Use of artificial intelligence to explore how SDGs intervene in nuclear regulation, both in the CSN and in other regulators. |
| | | 3.3.8. Innovative actions to be developed within the nuclear field that address the SDGs established in the 2030 Agenda. |
| RESEARCH AND DEVELOPMENT | 3.4. Others to be determined. | 3.4.1. New licences (nuclear fusion facilities and others). |

# CSN 2021-2025 R&D&I Plan

Colección Documentos I+D
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CSN CONSEJO DE SEGURIDAD NUCLEAR