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# Safety challenges in Spain's nuclear industry according to sector experts

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ABSTRACT

Safety is a key aspect for the continuity of nuclear energy as one of the most widely used energy options worldwide for producing electricity. However, previous studies have shown that the nuclear industry needs to meet social, technological, normative, environmental, economic, and organizational challenges. Due to this need, this study attempts to understand the challenges that Spain's nuclear industry faces with regard to safety. The study was conducted with 122 experts who responded to the question: *"What is the main challenge that Spain's nuclear industry faces in the field of safety?"* A discourse analysis was performed to identify the most important challenges and how they are characterized by experts.

Findings have shown that Spain's nuclear industry must face multiple and very diverse challenges. The main social challenge is the high concern for the continuity of Spain's nuclear industry, generated in large part by the socio-political context of uncertainty and the lack of social acceptance. Technologically, lifetime extension of the nuclear facilities in operation is the main challenge. The experts do not note other challenges present within the industry, such as ensuring new technological developments or building new nuclear plants. Regarding normative challenges, integrating new requirements within the current regulatory framework and coordinating the extensive and diverse existing regulation are noteworthy. The main economic challenge lies in achieving an efficient economic management system that ensures the nuclear plants' operation and makes them profitable. Organizationally, the main challenges are the generational shift and organizational learning. It is noted that the experts do not indicate other organizational issues that have been involved in important events within Spain's nuclear industry. Finally, the experts do not indicate any environmental challenges related to safety.



## 1. Introduction

The use of nuclear energy for generating electricity is one of the most important energy options worldwide (Organisation for Economic Co-operation and Development/Nuclear Energy Agency -OECD/NEA-, 2012a; International Atomic Energy Agency -IAEA-, 2014a). The nuclear-based energy supply is estimated to comprise approximately 14% of the world's electricity, and 21% of the electricity in member states of the Organisation for Economic Co-operation and Development (OECD) (OECD/NEA, 2012a). Currently, there are 438 operational nuclear reactors worldwide, and they are spread throughout more than 25 countries (IAEA, 2015). It is important to note that nuclear energy produces electricity without carbon emissions and other climate-relevant gases and that it provides a stable supply of electrical energy (Mari, 2014; Abu-Khader, 2009).

However, the continuity of the nuclear industry as a significant energy supplier seems to be dependent on the resolution of certain problems: "*concerns about safety, its technical complexity, the need for long-term management and disposal of nuclear waste, the complicated regulatory and legal requirements, and the large-scale investments required to build nuclear power plants*" (OECD/NEA, 2012a:13). Some of these concerns, including those regarding safety and radioactive waste management, have followed the commercial nuclear industry since its beginnings (Weart, 2012). Other more recent matters derive from important structural changes in the electricity market (IAEA, 2003).

Indeed, in recent decades, the nuclear industry in Western countries has had to adapt to processes of economic deregulation of electricity markets in a setting conditioned by cheaper energy production that is kinder to the environment and ultimately safer (Garcés, 2014). The industry has been required to adapt to a series

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of changes "*without compromising safety in any instance*" (Wahlström, 2004). The management of change in the nuclear industry has been identified as a critical topic with the objective of guaranteeing safety and preventing the occurrence of accidents (IAEA, 2003). On the other hand, the discussion about safety has emerged with renewed strength in the wake of the Fukushima catastrophe, reopening the political and social debate concerning the safety of nuclear technology with commercial aims.

In this context, a certain process of reflection is taking place concerning the future of the nuclear power industry. Some of the international nuclear organizations have identified the most important problems facing the international nuclear industry (e.g., OECD/NEA, 2012b; IAEA, 2014a; OECD/NEA/International Energy Agency -IEA-, 2015). Additionally, from the academic field, studies have been focusing on identifying the most important challenges for the nuclear sector (e.g., Deutch et al., 2003; Wahlström, 2004; Kettunen et al., 2006, 2007; Ramana, 2009).

The work presented in this article is framed in this context of questioning and reflection with regard to the future of the nuclear industry. Our investigation aims to identify the challenges that, according to sector experts, Spain's nuclear industry must confront and resolve to continue operating safely in the long term. This investigation has attempted to understand the nature of these challenges and the details that define them.

## 2. Main challenges for the nuclear industry

"Challenges" refers to a diverse set of difficulties or obstacles. These challenges can also be defined as "*seldom issues that can be approached and coped with in isolation*" (Wahlström, 2004:22). Other authors refer to this same idea, using the term "tension" "*to refer to a generic priority setting or resource allocation challenge, or to a challenge of balancing two or several at least partly conflicting objectives or expectations*" (Kettunen et al., 2007:426).

This study focuses on safety challenges assuming that organizations confront internal but also external challenges that require organizations to adapt for survival (Lawrence and Lorsch, 1976). Along these lines, socio-technical safety model by Rasmussen (1997, 2001; Rasmussen and Svedung, 2000) postulates that organizations are understood as open systems that are influenced by the changes in their environment (e.g. economic, regulatory, political aspects). Consistently, this model acknowledges safety is an emergent property of the system that arises from the interaction between the social and technological systems.

Socio-technical safety model by Rasmussen (1997, 2001; Rasmussen and Svedung, 2000) is a well-established model in the field of safety research (e.g. Hale et al., 2010; Le Coze, 2015; Leveson, 2004). Its postulates are congruent with previous empirical studies conducted in the nuclear industry (e.g., Baumont et al., 2000; Deutch et al., 2003; Joskow and Parsons, 2009; Kettunen et al., 2006, 2007; Ramana, 2009; Wahlström, 2004) in that they have also acknowledged the relevance of social, technological, normative, economic, environmental, and organizational challenges to continue operating safely in the long term.

### 2.1. Social challenges

One of the social challenges that the nuclear industry faces is the social acceptance of nuclear energy (e.g., Deutch et al., 2003; Van der Zaman, 2008), which is influenced by the risk associated with it (European Commission, 2010). According to the last Eurobarometer concerning nuclear safety, 52% of the European population perceived nuclear power plants as a risk (European Commission, 2010). In Spain, 54% of the population was against nuclear energy, and 38% were in favour of shutting down all nuclear plants (Foro de la Industria Nuclear Española, 2015). Furthermore, the occurrence of adverse events influenced public opinion on an international level (OECD/NEA, 2010).

The degree of experience and knowledge concerning nuclear energy is another critical factor for social acceptance (OECD/NEA, 2010). Thus, among countries where nuclear energy is used, the population is more favourably predisposed to its use, is better informed, and has a better understanding with regard to nuclear matters (OECD/NEA, 2010; Consejo de Seguridad Nuclear, 2015). Nevertheless, in general, the population feels poorly informed and considers the information that it receives concerning nuclear safety to be insufficient (European Commission, 2010; Consejo de Seguridad Nuclear, 2015).

Finally, trust in institutions also influences the social acceptance of technological risks (Poortinga and Pidgeon, 2003). Social trust determines the assessment made concerning the risks and benefits associated with technological risks (Siegrist and Cvetkovich, 2000). In this manner, trust in risk management can compensate for a negative perception of these technologies just as, conversely, distrust can lead to the opposite (Renn, 2008).

### 2.2. Technological challenges

On a technological level, the ageing of nuclear facilities is one of the most important challenges (IAEA, 2009a; OECD/NEA, 2012b). Thus, it is necessary "*to detect ageing effects of structures, systems and components to address associated reductions in safety margins and to take corrective actions before loss of integrity or functional capability occurs*" (IAEA, 2009a:3).

Associated with the ageing of nuclear facilities, is a management challenge concerning technology obsolescence. "Obsolescence" can be described as a "*lack of spare parts, technical support, suppliers and industrial capabilities*" (IAEA, 2009a:7) affecting the safety and operation of nuclear facilities.

Additionally, the ageing of nuclear facilities has reignited the debate on the lifetime extension of nuclear power plants, which were mostly designed to operate between 30 and 40 years (Van der Zwaan, 2008). Currently, more than 50% of nuclear reactors in operation worldwide surpass the 30-year lifespan (IAEA, 2015). In the case of Spain, these figures reach up to 75%. Indeed, by 2018, all of the nuclear reactors will surpass their operational lifespans (Foro de la Industria Nuclear Española, 2014).

Finally, one of the most noticeable advances within the industry is the development of a new generation of nuclear facilities known as Generation IV (Generation IV International Forum, 2014). These facilities are expected to be more efficient, sustainable, safe, trustworthy, and competitive (IAEA, 2004; OECD/NEA/IEA, 2015).

### 2.3. Normative challenges

One of the normative challenges that the nuclear industry faces is harmonizing safety requirements on an international level so that they can be applicable to different countries (Tronea, 2010). In an attempt to respond to this necessity, international organizations competent in the matter of safety within the nuclear industry have established the most important guidelines to follow (e.g., IAEA, 2008). Nevertheless, differences exist in the implementation of these guidelines on a national level in matters of design, construction, operation, or regulations. For example, there exist nuclear plants with a similar design but different safety standards based on the country in which they are located (Tronea, 2010). Standardization may be possible by producing a standard European plan of review or an evaluation process of generic design that would be considered suitable for all nuclear safety regulators in every country in the EU (Tronea, 2010).

Moreover, it is necessary to develop an effective regulatory framework. In this sense, some of the risks stem from excessive regulations and the multiplication or duplication of regulatory requirements (OECD/NEA/IEA, 2015). In the coming years, safety requirements may become more demanding (Joskow and Parsons, 2012), exacerbating these challenges. It is important to note that "*by requiring highly resource demanding licensee procedures some possibilities for safety development can be delayed*" (Rollenhagen, 2006, 86).

Finally, the accident in Fukushima has led to an increase in safety requirements. For example, in the context of Spain, nuclear facilities have been subjected to a group of stress tests and have executed important changes such as the implementation of an alternative emergency management centre (Consejo de Seguridad Nuclear, 2012).

### 2.4. Economic challenges

Economically, the costs associated with the operation and maintenance of nuclear facilities pose a challenge (Joskow and Parsons, 2009), given that these have increased in the last few years as a result of the implementation of new requirements. Furthermore, this cost may increase in the future as the result of new requirements (Joskow and Parsons, 2012). Nevertheless, the operation of nuclear power plants is currently considered profitable in almost all European countries, even considering the economic cost involved in adapting the post-Fukushima safety requirements (OECD/NEA, 2012c).

Regarding economic competitiveness against alternative energy sources, the challenge resides in the initial economic investment necessary for building nuclear facilities (Joskow and Parsons, 2009). Although nuclear energy is able to handle its two main competitors (carbon and natural gas) in terms of global cost, the corresponding cost of the initial investment for the construction of a new facility is greater than that of other technologies (OECD/NEA, 2012c; Abu-Khader, 2009). This cost creates an obstacle for investors (Van der Zwaan, 2008). Indeed, a reduction in the operation and maintenance costs of nuclear plants may increase interest in nuclear energy (Deutch et al., 2003).

Finally, an economic cost that is too high may induce some owners to not renew their operating licenses and shut down their plants (Joskow and Parsons, 2012). Indeed, in Spain, the nuclear power plant in Garoña has been shut down since the end of 2012, waiting for the approval of its operating license renewal (Consejo de Seguridad Nuclear, 2015). A major reason for this shutdown was the new taxes on electricity production and spent nuclear fuel that had been approved by the Spanish government and were owed by the plant.

### 2.5. Environmental challenges

The management and storage of radioactive nuclear waste have been key challenges for the industry since its beginning (Abu-Khader, 2009; Deutch et al., 2003; Van der Zwaan, 2008). The management and final disposal of spent nuclear fuel and highly radioactive waste is especially critical (OECD/NEA/IEA, 2015).

Currently, different alternatives concerning waste management are being assessed (Abu-Khader, 2009; OECD/NEA/IEA, 2015). At present, however, no country has applied a definitive solution for storing highly radioactive nuclear waste. Some countries, such as the U.S.A., Finland, France, and Sweden, have made advances in underground geological storage (Van der Zwaan, 2008; Fundación para Estudios sobre la Energía, 2007), whereas other countries, such as the Netherlands, have opted for centralized storage facility.

In Spain, spent fuel is temporarily stored in fuel storage pools. Nevertheless, nuclear power plants have been required to either increase the number of fuel storage pools or build temporary storage facilities. At the end of 2013, the utilization level of fuel storage pools in Spain's nuclear power plants was more than 86% (Foro de la Industria Nuclear Española, 2014). Additionally, the construction of centralized temporary storage facility (CTSF) is scheduled for 2021 in accordance with the Sixth General Radioactive Waste Plan (ENRESA, 2009).

### 2.6. Organizational challenges

On an organizational level, safety culture has become a central topic within the nuclear industry (IAEA, 2009b; INPO, 2013). "Safety Culture" refers to "*norms and rules for handling hazards, attitudes towards safety, and reflexivity on safety practice*" (Pidgeon, 1991:135). It can also be defined as "*the structure and processes of an organization, which, because of their dynamic interplay, will subsequently influence the culture and, in due course, behaviour and performance*" of an organization (Guldenmund, 2010:1470).

The main international organizations have attempted to establish the aspects of safety culture that are critical within the nuclear industry (IAEA, 2006; INPO, 2013). Organizational learning, leadership, communication, decision-making, and management processes are some of the organizational processes that have been identified as important to develop a strong safety culture (IAEA, 2006; INPO, 2013). Additionally, these organizations highlight the importance of creating an environment that favours a questioning attitude, problem identification, and accountability on all organizational levels (IAEA, 2006; INPO, 2013). In this sense, it is fundamental that all personnel consider safety as a fundamental value (IAEA, 2002a, 2009b) and that management emphasize and convey its importance (IAEA, 2002b, 2009b; INPO, 2004).

Along this same line, the analysis of adverse events occurring within the nuclear industry (Baumont et al., 2000; IAEA, 2002b; INPO, 2004) also reveals the importance of organizational factors (Reason, 1997; Pidgeon, 1998; IAEA, 2013). A review of the most significant accidents occurring in different industries and countries concludes that these accidents were mainly the result of errors in "*design or technology; training; decision making; communication; preparation for the unexpected; and understanding of organizational interdependencies*" (IAEA, 2013:10).

In the European setting, some authors highlighted challenges such as contractor competency and skills, the recruitment of young people, and motivational problems (Wahlström, 2004). Other challenges are also noteworthy, such as maintaining personnel motivation, building a proper safety culture, fighting complacency, and managing mental and emotional strain (Kettunen et al., 2007).

Finally, in the Spanish context, an analysis of the most significant incidents from the last 10 years has been able to identify the most important factors that have contributed to their occurrences. Among other findings, weaknesses in documentary processes, the absence of a critical attitude, inadequate employee supervision, and weaknesses with regard to internal and external operational experience are worth highlighting (Germán et al., 2014).

## 3. Methodology

### 3.1. Objectives

The objective of this study was to establish the main challenges regarding safety faced by Spain's nuclear sector according to the views of sector "experts". The present study seeks to identify the group of challenges and to understand their main characteristics, analysing them based on the terms defined above.

With the goal of creating a textual corpus that would allow a

qualitative analysis of the information gathered, the following open-ended question was posed: *"What is the main challenge that Spain's nuclear industry faces in the field of safety?"* This question was included in an online survey. This technique was chosen because it allows researchers to obtain data from large samples quickly and exhaustively (Díaz de Rada, 2012; IAEA, 2014b). Additionally, by being anonymous, respondents can express critical views without fear of adverse consequences (IAEA, 2014b). Furthermore, in the nuclear sector, studies exist that have used this technique with the same goal (e.g., Deutch et al., 2003).

There were no word limits for responses to the question, nor were the participants provided with any precise definition of the term "challenge". The data were gathered between June and September 2013.

### 3.2. Study sample

The online survey was administered to a large group of experts in Spain's nuclear sector. There were two criteria that were required for inclusion in the panel of experts: a) having worked in the nuclear industry for a minimum of 10 years; and b) having a wide knowledge of Spain's nuclear industry. The sample included experts not only from Spain's nuclear power plants but also from the rest of the organizations belonging to Spain's nuclear sector (such as the task of waste management and nuclear fuel manufacturing).

Recruiting members for the group of experts was performed with the collaboration of a sectorial group in Spain's nuclear industry that included representatives from different companies. A total of 155 experts were invited to participate, with 122 ending up actually participating (a 78.7% response rate). Regarding the sample, it is noted that it was mainly composed of unit or department heads of the different nuclear organizations. In the following table, the characteristics of the organizations that participated in the study are shown (see Table 1).

### 3.3. Data analysis

A discourse analysis was conducted to identify the most significant challenges and how they were characterized by the experts. Following Potter and Wetherell (1987), an analysis of "interpretive repertoires" was performed, which made it possible to understand the manner in which the experts responded to the question, thereby giving meaning to the object of the question: *"main challenge in the field of safety"*. In other words, with the analysis of "interpretive repertoires", recurring patterns or specific and precise formulations of these "challenges" were identified by experts in Spain's nuclear sector.

Considered socio-technical safety model by Rasmussen and previous research related to challenges in the nuclear industry, the categories used for classifying the challenges in the Spain's nuclear industry were the following (see Fig. 1): social challenges; technological challenges; normative challenges; economic challenges; environmental challenges; and organizational challenges. It is assumed that these dimensions cover the majority of the challenges faced by nuclear organizations.


**Fig. 1.** Safety challenges categories (based on literature review).

## 4. Results

Next, a detailed description of the most significant challenges according to sector experts is shown.

### 4.1. Social challenges

Three social challenges were identified: sector continuity, social acceptance, and communication to the public (see Table 2).

To the experts, the challenge of "sector continuity" meant *"rising above the negative environment"* that threatens the survival of this industry in Spain. Some experts expressed it in more extreme terms: *"the feeling that the nuclear industry is dying"*. A *"background of uncertainty"* is noted, as is the need to promote the sector in a *"broad and objective way"*. The experts expressed the negative impact of politics in the industry, noting, for example, the *"intrusion of politicians"* or *"the politicization in technical aspects"*.

A second challenge consisted of recovering the social acceptance lost due to catastrophic events in the industry (*"rebuilding the sector's credibility after accidents such as those in Fukushima"*). The

**Table 1**
Participating organizations and the number of experts from each.

| Organization | Facilities | Status | Total experts |
|---|---|---|---|
| NUCLENOR | Garoña NPP | Suspended operation | 15 |
| CNAT | Almaraz I NPP | In operation | 35 |
| | Almaraz II NPP | In operation | |
| | Trillo NPP | In operation | |
| ANAV | Ascó I NPP | In operation | 19 |
| | Ascó II NPP | In operation | |
| | Vandellós II NPP | In operation | |
| IBERDROLA | Cofrentes NPP | In operation | 9 |
| ENRESA | Vandellós I NPP | Shut down – latency | 18 |
| | José Cabrera NPP | In decommissioning | |
| | El Cabril | In operation | |
| ENUSA | Juzbado Factory | In operation | 12 |
| ENSA | Maliaño Factory | In operation | 14 |

loss of social *"trust"* and *"credibility"* was noted as a challenging situation that needed to be reversed. This lack of social acceptance appeared to be understood by some experts as a problem of social perception. It is believed that changing the public perception may come about by demonstrating the industry's high safety standards (*"improving society's perception that the nuclear industry maintains high self-imposed demands regarding safety"*).

Regarding "communication to the public", two main ideas define this challenge. The first is transmitting the idea (and being able to convince the public) that Spain's nuclear industry is safe. The foundation would have to be a communication policy that conveys and shows citizens the high safety standards. It is assumed that information concerning safety practices and investment would result in the establishment of social acceptance (*"being able to transmit to the general population that Spain's nuclear industry is safe and makes daily efforts to continue being safe (…) into the future"*. A second element consists of addressing general ignorance (*"the lack of information"*) that citizens have with regard to the nuclear industry by means of ample and precise information.

**Table 2**
Social challenges related to safety in Spain's nuclear industry.

| Dimension | Categories | Sub-categories |
|---|---|---|
| Social challenges | Sector continuity | Context of uncertainty |
| | Social acceptance | Recovering trust |
| | | Improving public perception |
| | Communication to the public | Risk communication |
| | | Generic communication |

### 4.2. Technological challenges

Three technological challenges were identified: technological updating, lifetime extension, and safety maintenance (see Table 3).

The main technological challenge is linked to the "technological updating" of components and equipment due to the ageing of Spain's nuclear facilities, that is, attempting to achieve *"technological renewal before the obsolescence of the facilities makes them nonviable"*. This technological renewal should *"modernize the plants"* and replace *"obsolete equipment and instruments"* with current technology. The idea of *"technological maintenance"* is repeatedly insisted on. Some experts link this challenge to a limitation of resources (*"modernizing the plants in a setting with very strong budgetary restrictions"; "resources are limited"*). For other experts, the technological updating of equipment allows the plants to be safer and prevents catastrophic accidents. One expert questioned the large technological investments derived from Fukushima, countering them with necessary investments in technological maintenance ("[they are] *infrastructure and equipment that will possibly never be used"*).

The second technological challenge entails "lifetime extension". This challenge is composed of two elements. The first is getting the plants to operate for more time than they were designed to. The experts formulated this idea in the coinciding terms of *"extending the lifespan"* or *"prolonging the operation of the power plants"* for longer than established *("beyond 40 years"; "up to 60 years"*). A second idea stemming from this challenge is less precise, without settling on a time period, and only alludes to safety conditions as a guarantee of getting the plant to operate in the future, *"safer and more reliable plants that guarantee more operating years"; "operating safely in the long term"*.

Finally, the experts noted the challenge of "safety maintenance". This idea was expressed in equivalent terms: *"maintaining current safety standards"*. The idea of avoiding events or incidents with public impact was also stated, reiterating the idea that incidents should not affect the public. Safety would need to be ensured in a way that would prevent catastrophic incidents. The challenge would entail *"being prepared to ensure the protection of workers, the public and the environment in any situation"*.

**Table 3**
Technological challenges related to safety in Spain's nuclear industry.

| Dimension | Categories | Sub-categories |
|---|---|---|
| Technological challenges | Technological updating | Equipment obsolescence |
| | | Technological modernization |
| | | Equipment maintenance |
| | Lifetime extension | Extending the lifespan |
| | | Long-term safe operation |
| | Safety maintenance | Maintaining safety standards |

### 4.3. Normative challenges

The analysis shows two significant challenges for the sector at the normative level: the implementation of new regulatory requirements and the reasonable integration of these requirements (see Table 4).

The first challenge refers to the implementation of new regulatory requirements. The experts note that Spain's nuclear industry has to "*accept responsibility"* or *"adjust to"* a series of requirements stemming from a *"Post-Fukushima setting"*. It is specified that these changes must be *"efficiently implemented"* with the objective of ensuring or increasing safety. Some experts anticipate that there will be more changes in the future (*"there will be other kinds of consequences in the coming years"*).

The second challenge noted by experts entails the reasonable integration of the increased volume of requirements with which Spain's nuclear industry is faced. There are three ideas that define this challenge: a) the limited time available for the industry to address all of these regulations (*"all of them are urgent"*); b) the need to clarify these new regulations (*"regulation overlapping"*); and c) the negative effects on safety that this regulation accumulation may involve (*"answering to too many obligations could miss the essence of a safe operation"*). For experts, this increased number of regulatory requirements could have a negative effect (*"the excessive regulatory framework"*).

**Table 4**
Normative challenges related to safety in Spain's nuclear industry.

| Dimension | Categories | Sub-categories |
|---|---|---|
| Normative challenges | New regulatory requirements | Post-Fukushima setting |
| | Integration of requirements | Temporary urgency |
| | | Clarification of requirements |
| | | Regulation accumulation |

### 4.4. Economic challenges

The experts indicated two economic challenges: having an economic investment and efficient economic management (see Table 5).

First, the need to improve economic investment for safety reasons was justified in terms of safety (*"safety needs a continuous investment in equipment renewal and in management and improvement processes"*). In some cases, the *"lack of investments"* is explicitly stated. The experts also refer to the difficulty in obtaining sufficient

economic resources.

Furthermore, the experts note the challenge in obtaining an efficient economic management of the industry. Two ideas define this challenge: a) optimizing costs and b) balancing safety and productivity.

Regarding costs, the experts generally referred to the term "cost" in a negative sense, as a loss that must be minimized (*"the need to optimize costs"*). On the other hand, some experts warned about the risk of focusing the nuclear industry's management on controlling costs instead of on technical aspects (*"the temptations of minimizing costs"; a more technical management and less economistic"*). The regulation requirements stemming from Fukushima were also referenced as something that *"could generate very costly investments"*. In this sense, some experts considered these regulations to be a threat to the industry because of their economic costs (*"the operation of a nuclear power plant can be economically unviable, gaining very little safety"*).

With regard to the safety-productivity dilemma, the experts noted the current emphasis would be to focus on safety over productivity. The challenge would be to *"obtain a reasonable safety vs. economic profitability relationship"*. Maintaining the emphasis on safety was referred to repeatedly (*"maintaining our way of working where safety takes precedence over productivity"*).

**Table 5**
Economic challenges related to safety in Spain's nuclear industry.

| Dimension | Categories | Sub-categories |
|---|---|---|
| Economic challenges | Economic investment | Lack of investment |
| | | Insufficient economic resources |
| | Efficient economic management | Optimization of costs |
| | | Safety - productivity dilemma |

### 4.5. Organizational challenges

The three organizational challenges that Spain's nuclear industry faces are the generational shift, the consolidation of the safety value, and organizational learning (see Table 6).

The main organizational challenge for experts is linked to the process of a "generational shift". There needs to be a method to ensure that, after the *"retirements and renewals"* of a significant portion of personnel, the technical management of nuclear facilities remains in the hands of highly qualified people who are capable of efficiently addressing the needs of these nuclear facilities.

Two critical aspects in the replacement process can be distinguished: a) the transmission of highly specialized technical knowledge (*"technical know-how"*) and b) the transference of other intangible elements linked to elements of motivation and attention to safety. Achieving these tasks must ensure that *"the employees have an in-depth knowledge of how to do their jobs and obtain a high commitment, putting the facility's safety as the main objective"*. The idea of arranging an excellent human team is explicitly stated. The excellence of the human team would occur by promoting a process of continual improvement for the entire nuclear facility workforce on an organizational level (*"reaching excellence in the work behaviours and practices of all personnel who active in the organization"*).

A second challenge entails "consolidation of the safety value" to induce all active personnel in the nuclear sector to work safely and be aware of risks. It is said that nuclear organizations must assume a firm commitment to convey the importance of this value (to all of their members), that is, the importance of safety. It is necessary to "*improve the safety culture and raise awareness in the job positions of all personnel*".

The underlying idea of the process of consolidating the safety value is realized by understanding safety as a critical element in all work activities and practices in the industry and by fulfilling the standards of safety regulations at all times. Meeting this challenge *"happens by achieving an awareness in all employees of everything that needs to be done regarding safety regulations"*. The idea that safety depends on everyone is emphasized, and simple actions can contribute to diminishing the importance of safety. As one expert put it: *"It is necessary to make everyone participate; all employees, suppliers, and everyone else involved are responsible for safety, given that an accident can occur in the facility, even from the most insignificant task. This cannot be forgotten, even though some activities are repetitive"*.

Finally, the last challenge is related to organizational learning. Two elements are defined: a) personnel's responsibility of facing problems and b) operational experience. Regarding the responsibility of facing problems, an ideal worker in the nuclear sector would demonstrate a proactive attitude, commitment, and transparency in the process of problem identification and resolution (*"involvement and cooperation of personnel at the time of researching and looking for solutions in the face of potential defects")*. Another aspect mentioned is maintaining an inquisitive attitude in the industry (*"maintaining and also increasing the interrogating and questioning attitude in matters of safety"*) in terms of daily labour practices (*"when the routine takes over our day-to-day tasks"*). With regard to operational experience, experts indicate the possibility of acquiring information to transform it into knowledge that improves the organization. In this sense, the challenge is focused on paying more attention to the information provided by the operational experience (*"learning about the individual's and other people's operational experience"*).

**Table 6**
Organizational challenges related to safety in Spain's nuclear industry.

| Dimension | Categories | Sub-categories |
|---|---|---|
| Organizational challenges | Generational shift | Technical know-how |
| | | Quality of human resources |
| | Consolidation of the safety value | Safety culture |
| | Organizational learning | Accountability in the face of problems |
| | | Operational experience |

## 5. Discussion

The objective of this study is to explore the viewpoint of experts concerning the challenges related to safety that Spain's nuclear industry must face. The study does not set out to list or count challenges but attempts to understand how they are conceived and under what terms they are defined. Although some results generally coincide with previous studies concerning the future challenges of the nuclear industry (Kettunen et al., 2006, 2007; Wahlström, 2004), the findings of the present study demonstrate the existence of specific challenges in the Spanish sector. Next, the findings of each element of the analysis are discussed.

The main social challenge for Spain's industry appears to be in securing its continuity. This concern stands out above what would be a more generic concern, improving its social acceptance. It is important to report that, while the study was being conducted, the renewal of the operating license of Santa María de Garoña, the

oldest nuclear power plant in Spain, was pending. At this crossroads, the main challenge, according to the experts, is ensuring the future continuity of the different plants (and not only Garoña). This challenge is defined by the experts in a certain dramatic tone (the nuclear industry is "dying"), with appeals to the clarification of the period of uncertainty (attaining an operating license for more time than initially expected), and with a vision of the legislative organizations, as political agents who meddle in technical aspects. The process of negotiation between the government and the electric company is perceived as a process of political intrusion concerning technical aspects in which "politicians" do not have technical competence.

On the other hand, the experts' assessment concerning the low level of public acceptance of Spain's nuclear industry is consistent with previous studies (European Commission, 2010; Foro de la Industria Nuclear Española, 2015). The experts appear to attribute this low social acceptance primarily to the media impact of the Fukushima catastrophe (the idea of "recovering" trust is referred to repeatedly). The experts' view seems to reside in the following two axioms: a) the low level of social acceptance of Spain's nuclear industry is due to a misunderstanding, a mistaken social perception; and b) to correct this erroneous perception, it is necessary to give the public precise information on safety standards. In other words, to deal the lack of information among the public (and its mistaken perception) it is necessary to develop an ample communication policy that is centred on safety aspects.

The main technological challenge that is attributed to Spain's nuclear industry is to maintain operations (in a safe way "as is done currently") in spite of the ageing of the facilities and nuclear equipment. This challenge corresponds to the goals stated in the international organization reports regarding the international nuclear industry (IAEA, 2009a; OECD/NEA, 2012b). For the experts in the study, the key would be achieving "technological maintenance" by replacing obsolete equipment and instruments in a setting of declining economic resources. A second technological challenge entails the lifetime extension of the plants. This challenge is defined in generic terms, that is, without providing concrete details about replacing large equipment or systems. The experts also do not allude to the construction of new nuclear facilities. Based on the views of the experts, it would seem that the survival of the industry in Spain depends only on extending the lifetime of current plants rather than on building a new generation of nuclear power plants or developing new technological advances.

Concerning normative challenges, the results show that the experts' views are aligned, in part, with the main challenges of the international industry. The principal regulatory bodies note the need to succeed in harmonizing the existing extensive and diverse regulations (OECD/NEA/IEA, 2015). These organizations also advocate encouraging what would be a collaborative focus between the regulators and licensed professionals who would implement the regulatory requirements in an integrated manner and in accordance with their impact on safety (INPO, 2014). The information from our study does not provide evidence supporting this type of focus by experts in the Spanish sector. On the contrary, the following belief appears to be shown: "we are safe in spite of the regulation", that is, the regulatory framework is seen as excessive and counterproductive for a safe and efficient operation. Put differently, the experts believe that regulatory norms are more of a burden to safety than an added value.

A challenge that seems non-existent for Spain's industry is the environmental challenge. It is interesting that the issue of waste management was not concretely mentioned by the experts surveyed in this study, considering its controversial nature since the beginning of the nuclear industry (Weart, 2012). There is only some specific mention of the need to build (according to the planned calendar) centralized storage for highly radioactive waste. There is also no mention of the debate regarding the type of long-term sustainable economic solution (geological storage vs. centralized storage). The experts do not appear to consider waste management to be an important industry challenge to safety in the Spanish context.

Concerning economic aspects, Spain's industry needs to be able to obtain an efficient economic management that ensures the plants' operation and makes them profitable, according to the experts in the study. This viewpoint coincides with that of other studies (Deutch et al., 2003; Joskow and Parsons, 2012). It should be noted that there is a certain controversy over the term costs among the experts. Although a favourable view is mainly assumed regarding the policy on cost control, there is a contrary view on the emphasis of that control due to the possibility of coming into conflict with technical needs. The experts also make coinciding statements regarding the need to achieve and maintain a sufficient economic investment to ensure safe operations.

Regarding organizational challenges, the study provides a specific clarification of the Spanish sector's priorities. Compared to the diversity of organizational factors established by existing models (IAEA, 2009b; INPO, 2013), the analysis shows a somewhat compact and restricted view by the experts that is specifically centred on factors linked to nuclear personnel (knowledge, experience, and attitudes/values). Additionally, everything seems to pivot not only around the generational shift (transferring the value of safety) but also around organizational learning. On the other hand, it is interesting to note some significant omissions: among other aspects, the experts do not note the importance of procedures or continuous training as key factors in the generational shift. They also do not note the organizational factors that were mostly present in the more significant events in Spain's nuclear industry over the last decade (events with an INES classification that are greater than or equal to 1) which are the weaknesses within the documentary processes or a lack of adequate supervision on the job (Germán et al., 2014).

Regarding the implications of the study, the following issues are worth highlighting. First, the idea of "safety" that emerges from this study is a critical element that serves to justify everything, from the social challenges (as an element that determines social acceptance) to the technical challenges (such as obtaining a lifetime extension of the plants in operation). The omission of environmental challenges related to safety is noteworthy; a safety that, according to this study, should be balanced and competitive. Safety is presented as a fundamental aspect for the nuclear industry but, simultaneously, with certain economic conditions attached; that is, it has to be compatible with viable economic management. On the other hand, there is a certain paradox between the emphasis on safety as a basic principle simultaneous to a negative connotation regarding the regulations derived from catastrophic events (Fukushima) that require making large technological and organizational changes after increasing safety.

Second, the results support models such as the socio-technical model applied to High Reliability Organizations (Rasmussen, 2000). The nuclear organization is seen as an open system that is influenced by the socio-political environment. These results transmit an idea of defeat by the normative and economic challenges due, at least in part, to external pressures. The environment is not seen as a source for resources but rather as a source of pressures and threats.

Third, it is necessary to note some of the limitations of this study. First, the study identifies challenges according to the viewpoint of a determined group of professionals in the nuclear sector who participated in the study. This study does not consider the viewpoint of other social actors that play specific roles in Spain's

nuclear sector (such as investment companies, public administrations, regulatory bodies, ecological associations, etc.) and that may have a different perception or emphasize other challenges from those found in this study. Future studies can confirm the results of this study with the viewpoint of other stakeholders in Spain's nuclear sector. Second, it is also worth considering that the "experts" in this study are professionals in the nuclear sector with industrial and functional dependency on organizations within the sector. Scientific and academic experts may be equally worth adding to the study.

## 6. Conclusions

Our results show that, according to experts, Spain's nuclear industry must face multiple and diverse challenges to continue operating in the future. Some of the challenges noted generally coincide with the main challenges of the international nuclear industry. Nevertheless, the study reveals a definite local typography in matters of safety for Spain's nuclear industry. Thus, the investigation provides a specified characterization and particular modulation for general challenges that are able to produce a precise and concrete image of the reality of the nuclear industry in Spain. It offers a general outlook that highlights specific elements but, simultaneously, omits and diminishes certain relevant topics within the nuclear industry.

As a way of summarizing, the expert's viewpoint on the industry can be outlined along the following main lines: a) a large concern for the continuity of the industry in the face of political interference; b) concerns about obtaining a lifetime extension for the plants in operation (over ensuring new technological developments or building new nuclear plants); c) risks concerning safety in environmental aspects are not discerned (such as waste management or the provisional nature of temporary storage facilities in the power plants); d) emphasis on the need to be able to integrate new regulatory requirements that are viewed as excessive; e) attaining efficient economic management of the nuclear organizations through controlling costs; and f) the generational shift and learning as the most important organizational challenges (omitting relevant factors involved in numerous events in Spain's industry such as weaknesses in the documentary processes or inadequate work supervision).

Finally, we note that the results support the socio-technical model applied to high reliability organizations (Rasmussen, 2000), understanding the organization as an open system that is expected to be influenced by factors external and internal to the organization.

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