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A comparative legal study of radioactive waste disposal in France and Spain

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Abbreviations

ANDRA	*Agence Nationale pour la Gestion des Déchets Radioactifs*
ASN	*Autorité de Sûreté Nucléaire*
BOE	*Boletín Oficial del Estado*
CEA	*Commissariat à l'Énergie Atomique*
CIEMAT	*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas*
CIRES	*Centre Industriel de Regroupement, d'Entreposage et de Stockage*
CSN	*Consejo de Seguridad Nuclear*
CSTFA	*Centre de Stockage des Déchets de Très Faible Activité*
CTS	Centralised Temporary Storage facility
DBD	Deep Borehole Disposal
DGR	Deep Geological Repository
ECSC	European Coal and Steel Community
EEA	European Environmental Agency
ENRESA	*Empresa Nacional de Residuos Radiactivos, S.A.*
ENUSA	*Empresa Nacional del Uranio, S.A.*
EU	European Union
EURATOM	European Atomic Energy Community
HLW	High-Level Waste (in France)

IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IL-LLW	Intermediate-Level Long-Lived Waste (in France)
JEN	*Junta de Energía Nuclear*
Joint Convention	Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management
LL-LLW	Low-Level Long-Lived Waste (in France)
MDG	Millennium Development Goals
MIT	Massachusetts Institute of Technology
MOX	Mixed Oxide Fuel
NASA	National Aeronautics and Space Administration
NEA	Nuclear Energy Agency
NECP	National Energy and Climate Plan
NIMBY	Not in My Backyard
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
OECD	Organisation for Economic Cooperation and Development
P-239	Plutonium-239
PGNN	*Plan General de Residuos Radiactivos*
PNGMDR	*Plan National de Gestion des Matières et des Déchets Radioactifs*
PNIEC	*Plan Nacional Integrado de Energía y Clima*

R+D	Research and Development
RAA	High-Level Waste (in Spain)
RASWASS	Radioactive Waste Safety Standards Programme
RBBA	Very Low-Level Waste (in Spain)
RBMA	Low- and Intermediate-Level Waste (in Spain)
RE	Especial Waste (in Spain)
SDG	Sustainable Development Goals
TPNW	Treaty on the Prohibition of Nuclear Weapons
U-235	Uranium-235
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
US	United States
WHO	World Health Organisation

Abstract

This study focuses on presenting how nuclear power has been reintroduced in the energy debate during the last few years, as it is being discussed how this low-carbon energy generating technology can help mitigate the effects of climate change. Furthermore, it analyses the advantages of nuclear power, but especially the disadvantages that nuclear technologies need to overcome to rise to the challenge of climate change. In particular, the disposal of radioactive waste.

The concept of radioactive waste and the current methods for its disposal are explained before studying what international legal instruments regulate about the issue. Following this, especial reference is made upon the specific legal frameworks affecting the disposal of radioactive waste in France and Spain and the current solutions they offer for a waste that is mainly generated by their nuclear power plants.

Key words: Nuclear Energy; Nuclear Law; Radioactive Waste; IAEA; Nuclear Industry in France; Nuclear Industry in Spain.

I. Introduction

A. Research topic

If the infamous COVID-19 had not decided to come into existence in the late 2019, in the year 2020 we would have kept talking about climate change. Just because we are no longer seeing it in the news, it does not mean it has stopped its effects. Just as an example of how it is still here, the *Copernicus Climate Change Service*, the European climate observing program dependant on the European Commission, reported that the past winter (from December 2019 to February 2020) was “by far the warmest on record for Europe”[1].

Climate change has been quite an issue in the last few years. It can be defined as a study that deals with the variations in climate variables on different time scales, while also attempts to identify the possible reasons of such alterations. During the Earth’s history, there have been many occasions in which the climate of the planet has suffered from many changes, but the one we mostly refer to when we talk about *climate change* is the one we are undergoing now and since the beginning of the industrial revolution, due to human activities. Never before, the human species were able to affect the Earth’s climate at such a high speed, and it caused global warming issues to arise.

Global warming is used to define the ongoing increase in temperatures around the globe due to certain gases (known as a whole as greenhouse gases) that are trapped in the air masses that surround the planet and that prevent heat from escaping the Earth. These changes contribute to climate change to the extent they can vastly alter the conditions of life as we know it (increase of the sea-level and reduction of lands, extinction of flora and fauna species unable to survive in their newly-conditioned habitats, etc.) and are a big threat to the future of the Earth. That is the reason why tackling global warming might be the most remarkable challenge of our time.

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[1] COPERNICUS CLIMATE CHANGE SERVICE, *Surface air temperature for February 2020*, retrieved the 21st March 2020 from https://climate.copernicus.eu/surface-air-temperature-february-2020.

In Europe, the energy sector accounts for the largest emitter of greenhouse gases, as it relies largely on fossil fuels[2]. Fossil fuels, such as gas, oil, or coal, produce greenhouse gases which contribute to global warming. If we combine these two statements, it is obvious that finding alternatives for energy production may be a great way to fight this global warming issue. *Renewable energy* is one option. The concept comprises energy that is produced using sources such as the wind, sun or water streams, which are sources that can be replenished and cannot be depleted within a human's life time, rather than using fossil fuels, which can be depleted and cannot be replenished in such a short fraction of time. But while renewable energy is better for the environment in many ways, there are still a few problems with it. For example, the lack of availability of power, because they rely on natural resources that are uncontrollable by humans (*i.e.* sun or wind), or the restriction in location choices.

Besides renewable energy, we do have another option in the block of non-renewable energy sources that offers low-carbon energy production: *nuclear power*. Nuclear power plants, while on operation, produce no greenhouse gas emissions, unlike fossil-fuelled thermal power plants. In fact, most of the suggested pathways to achieve decarbonisation in the energy production sector agree that increasing the role of nuclear power is a good option to mitigate the effects of climate change. And there is room to improve. While the share of nuclear energy has remained more or less constant at 12% in Europe, despite the growth in importance of renewable energy sources, the share of oil and natural gas still account for over 70% on the primary energy supply[3].

It seems that we have an easy choice to make before our eyes, but further reflection is needed. Nuclear power plants might sound very promising, but they pose many other problems and entail a series of dilemmas that need to be considered before we inundate Europe with new nuclear plants. For the public opinion, their main fear of nuclear plants comes from the risk of nuclear accidents, such as the *Chernobyl*

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[2] EEA, *Adaptation challenges and opportunities for the European energy system: Building a climate-resilient low-carbon energy system*, EEA Report, No. 1/2019, p. 16.
[3] *Ibid*.

disaster, in which the risk is not necessarily high, but the consequences are greatly devastating. Nevertheless, we will focus this research on the topic of nuclear waste, and radioactive waste in general.

B. Research structure

If the carbon footprint is the bequest of the use of fossil fuels, nuclear waste is the undesired legacy of nuclear power plants. Nuclear waste is a hazardous by-product of the process that takes place in nuclear plants to produce energy. The exposure to it can be harmful for human and the environment in general. Due to its high level of radioactivity and the long time it takes for that radioactivity to decrease to non-harmful levels, it must be correctly managed, but most importantly, disposed of. This will be the subject matter of this research.

Accordingly, this research will attempt to draft which is the regulatory framework of radioactive waste disposal and to draw a comparative study on how it is policed at a European Union (EU)/EURATOM level and at a national level. The countries we have chosen are France, a country with a prominent nuclear energy sector, and Spain, in which nuclear energy has a much smaller role in comparison to France, but still needs to manage the disposal of its radioactive waste. The goal will therefore be to study how the process of radioactive waste disposal is dealt with by those two different countries, in accordance to their especial needs, and draw conclusions about the adequacy of nuclear power as a "weapon" to fight the effects of climate change. If radioactive waste is such a drawback of nuclear power, the legal framework for its management and disposal must be, at least, satisfactory, to be able to make the *nuclear* choice.

C. Methodology

The methodology that will be used to find the answer to our questions will be a combination of legal science with other disciplines, such as nuclear science, energy science, chemistry or engineering, and with other disciplines as sociology, since nuclear power plays a controversial role as an energy-generating technology in society.

However, our approach will be characterized by the predominance of the legal analysis. In this way, the other disciplines will only provide additional interpretative support for the legal focus and they will be useful to understand the legal texts when they become too technical for general knowledge on radioactive waste.

In base of this methodology, the international normative that could affect the national regulations on radioactive waste management will be analysed. Once we see the problem and the general aspects of radioactive waste, after a general framework is set, the cases of France and Spain will be examined. Firstly, the current status of their nuclear energy industries will be seen in broad strokes to understand the magnitude of their radioactive waste problem. Secondly, we will see the legal and institutional framework in which radioactive waste disposal takes place in France and Spain. Finally, the focalisation will turn to the actual development of their radioactive waste disposal strategies to assess the adequacy of the legal framework, as well as their efficacy.

The final objective of this work is to provide some clarity on our doubts regarding the suitability of nuclear power as a mean of fighting climate change, but also that people who read this research are encouraged to delve more deeply in the topic of radioactive waste, which is unknown to society, and help to find a consensual disposal solution for it, as it is a subject that requires the compromise of many special interest groups within society.

II. Nuclear power and radioactive waste

A. A brief history of nuclear power

Nuclear power typically needs to be addressed from two different perspectives: the extraction of nuclear energy for military purposes (originally, the development of atomic bombs) and the use of nuclear energy for peaceful applications (the most important, the generation of electricity). But regardless of this division, both dimensions are interrelated, as the existence of the second one is owed to the first.

Before seeing the evolution of nuclear power through the time, it is useful to understand how the process of obtaining energy with it is. In a nutshell, in nuclear reactors, Uranium-235 (U-235), a kind of isotope that is easily fissile, is bombarded with loose neutrons, absorbs them, and becomes unstable. This causes its split into two lighter atoms (fission products) but also release part of their energy as heat. A few neutrons are also released along with the heat, which can hit other atoms and cause more fission, that is, a series of fissions (chain reaction). In fact, under the right conditions, this can turn into a self-sustaining chain reaction, which releases a great amount of heat, which in turn can be used to generate electricity[4].

After understanding these basics of nuclear energy, it is easy to comprehend what happens in nuclear power plants. Just like in any other coal-fired plant, water is boiled and its steam turns turbines to generate electricity. The difference relies on how the water is heated: while in coal-fired plants, the coal (or any other fossil fuel) is burned to heat the water, in nuclear power plants, a self-sustaining chain reaction is used the boil the water.

The ability of nuclear fission to generate heat and, therefore, electricity would not have been discovered if countries had not been so focused in the development of their nuclear weapons programmes. In the early years, scientists worked on developing breeder reactors. They were designed so that one of the fission products

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[4] US DEPARTMENT OF ENERGY, *The History of Nuclear Energy*, DOE/NE-0088, retrieved the 22nd March 2020 from https://www.energy.gov/sites/prod/files/The%20History%20of%20Nuclear%20Energy_0.pdf.

was Plutonium-239 (P-239). P-239 is a fissionable isotope, just like U-235, but it is more accessible, as it can be chemically extracted from the spent fuel of the breeder reactors and can be used in atomic bombs. In fact, the sole reason to be of the first nuclear reactors was to produce plutonium for their own countries' nuclear weapons programmes. This is important to remember when we address the issue of proliferation risks, as a downside of nuclear energy.

Therefore, concurrently to the development of the military applications of nuclear power, the ability of nuclear fission to generate electricity was spotted. A big obstacle from the beginning, though, was the lack of alliances between countries to jointly put resources and build up nuclear energy programs together. Countries researching alone meant dealing with the high costs and risks intrinsically related to nuclear energy with no help, but as the pursuance of nuclear weapons was still of interest for most countries in the aftermath of the Second World War, economic criteria was not a priority and it allowed the *naissance* of civil nuclear energy.

Pushing the vision towards the generation of energy forward was helped by the first international actions that were done related to nuclear energy. In 1953, US President Dwight D. Eisenhower delivered his *Atoms for Peace* speech in the United Nations General Assembly (UNGA), to encourage the deviation of nuclear energy towards civilian uses, which in turn also boosted the creation of the International Atomic Energy Agency (IAEA)[5].

> "*The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose*"[6].

At the same time, under the United Nations (UN) framework, the *First* (1955) and the *Second* (1958) *Geneva Conferences on the Peaceful Uses of Atomic Energy*

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[5] WALLS, J., "Nuclear Power Generation – Past, Present and Future", in HARRISON, R. M. *et al.*, *Nuclear Power and the Environment*, Royal Society of Chemistry, 2011, p. 6.
[6] Article II of IAEA Statute of 23rd October 1956.

were held, in which the capability of nuclear power to help meet the world's energy requirements was highlighted[7].

Post-war Europe was also committed to nuclear power. The members of the former European Coal and Steel Community (ECSC) signed the *Treaties of Rome* (1957), and with it, established the creation of the European Atomic Energy Community (EURATOM), to "contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries"[8], as stated in the Article 1 of the EURATOM Treaty.

Thus, in this context, the agenda of many countries spun around the development of the civilian uses of nuclear energy. For that reason, the number of nuclear plants in the world started to grow and consequently the electricity production from nuclear sources[9]. Many preferred nuclear over fossil fuels for the perceived lesser harmful effects on the environment. It also proved to be a better option during the oil crisis, when energy independence and security became key for many countries (*i.e.,* see *le plan Messmer*[10] in France)[11].

This period in which the optimistic visions remained dominant was about to change. In the late 1970s and during the 1980s, two factors were decisive to slow down the growth of nuclear power. On one hand, the inflation during the oil crisis made capital-intensive investments, like nuclear plants, harder to bear. On the other, the first two serious accidents reinforced the opposition to nuclear power: *The Three Mile Island* partial core meltdown (1979) in the US and the fire and core meltdown at *Chernobyl* (1986) in the former Soviet Union[12]. The repercussion of these

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7 IAEA, "The Geneva Conference – How it Began", *IAEA Bulletin*, 6(3), 1964, p.1.

8 Treaty Establishing the European Atomic Energy Community of 15th March 1957.

9 IEA STATISTICS, *Electricity production from nuclear sources (% of total)*, The World Bank, 2015.

10 VINDT, G., "1974: le plan Messmer choisit l'option du tout-nucléaire", *Alternatives Economiques*, 069(9), 2014, retrieved the 22nd March 2020 from https://www.alternatives-economiques.fr/1974-plan-messmer-choisit-loption-nucleaire/00067465.

11 KRYMM, R., "A New Look at Nuclear Power Costs", *IAEA Bulletin*, 18(2), 1976, p. 2.

12 NIEL, J., *et al.*, "Que s'est-il passé à Three Mile Island, Tchernobyl et Fukushima Dai-ichi ? Et où en est-on aujourd'hui?", *Annales des Mines - Responsabilité et Environnement*, 97, 2020/1, p. 25-30.

accidents led to most countries deciding on phasing nuclear power out. Academics started to emphasise the risks of nuclear over its benefits, and the lack of high-level radioactive waste disposal facilities did not help when considering nuclear power from an environmental perspective.

B. New opportunities for nuclear energy

This trend of people making their cases against nuclear power experimented variations with the new millennia. In the 21st century, three factors could change the odds for nuclear power worldwide.

Firstly, the increase of energy demand, due to the quick growth of the world population and the industrialisation and urbanisation process in which emergent countries are caught up in (*i.e.* India, Southeast Asia and China)[13]. Secondly, the raised importance of energy security, especially in European countries[14], very dependent on imports and that can be benefited from nuclear energy as a reliable, affordable, and accessible source of energy. And thirdly, the need to redirect the energy generation processes towards a low-carbon future to fight climate change[15].

Taking these three factors into account, it is obvious how nuclear energy might be able to play a role in the set of sources of energy of the future, hand in hand with the rest of the renewable energies, as an alternative to the fossil fuels that are currently being used. Nuclear can be a secure source of energy, not as reliant on price fluctuations and geopolitics as fossil fuels, like natural gas or coal. Since it does not depend as much from imports (even if for some countries, it is still needed to import enriched uranium), the supply of energy is reliable, competitive and available at demand. And unlike the generation of electricity with fossil fuels, it

[13] IAE, *World Energy Outlook 2019: Executive Summary*, 2020, retrieved the 28th March 2020 from https://iea.blob.core.windows.net/assets/1f6bf453-3317-4799-ae7b-9cc6429c81d8/English-WEO-2019-ES.pdf.
[14] DIRECTORATE-GENERAL FOR ENERGY, *EU energy trends to 2030*, European Commission, 2009.
[15] EUROPEAN COMMISSION, *A Roadmap for moving to a competitive low carbon economy in 2050*, COM (2011) 112 final, 8th March 2011.

does not emit carbon dioxide in the process (discounting the amount related to the construction of reactors).

It goes without saying that nuclear energy is not the only answer to address the issues previously stated. However, leaving nuclear out of the discussion can be a heedless thing to do, even with the public opposition towards nuclear since the accidents that ailed the nuclear industry in the late 20th Century.

As the celebrated scientist James E. Lovelock said in his renowned article "Nuclear power is the only green solution" for *The Independent* in 2004:

> "Opposition to nuclear energy is based on irrational fear fed by Hollywood-style fiction, the Green lobbies and the media. These fears are unjustified, and nuclear energy from its start in 1952 has proved to be the safest of all energy sources. […] Even if they were right about its dangers, *and they are not*[16], its worldwide use as our main source of energy would pose an insignificant threat compared with the dangers of intolerable and lethal heat waves and sea levels rising to drown every coastal city of the world. We have no time to experiment with visionary energy sources; civilisation is in imminent danger and has to use nuclear - the one safe, available, energy source - now or suffer the pain soon to be inflicted by our outraged planet"[17].

Regardless of these promises of carbon-free energy, the challenges that the nuclear energy industry is facing nowadays must be considered as well. Despite the benefits of nuclear listed above, the fact remains that it is not a source of energy with no downsides. As a matter of fact, its disadvantages are not entirely negligible and have to be carefully examined.

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[16] The Italic is ours.

[17] LOVELOCK, J., "Nuclear Power is the Only Green Solution", *The Independent*, 24th May 2004, retrieved the 31st March 2020 from https://www.independent.co.uk/voices/commentators/james-lovelock-nuclear-power-is-the-only-green-solution-564446.html.

C. Current challenges of the nuclear energy industry

As we have previously seen, nuclear energy would be an adequate response for some of the current energy-related problems the world is facing. However, there are still a number of hurdles for nuclear energy to overcome, as it tries to find its place in the energy of the future.

i. Uranium availability

Despite the research done into fast breeder reactors, which would allow to obtain much more energy than from conventional reactors, the future of nuclear energy relies on the availability of uranium. Uranium, unlike the sun light, wind or water streams that power renewable energies, is a finite resource. Therefore, if we consider the expansion of nuclear power plants, we need to ponder what the current reserves of uranium are and how long they are assessed to last at current consumption rates.

Nevertheless, recent studies suggest that "there is a high degree of confidence that natural uranium can be provided at affordable costs well into the future"[18]. Furthermore, uranium is a commodity that has experienced high volatility in prices. When prices rise, further research on exploration and extraction is made because it increases the amount of economically extractable resources (*i.e.* from tailings, phosphate rocks, cooper leaches, etc.)[19]. For that reason, depletion of uranium resources cannot be considered as an argument against nuclear energy in the short term. There is more than enough time to find alternatives (*i.e.* unconventional resources, advanced reactor and fuel cycle technologies) before that time comes[20].

[18] MIT ENERGY INITIATIVE, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT Study*, Massachusetts Institute of Technology, p. 41.
[19] HANSEN, M.V., "World uranium resources", *IAEA Bulletin*, 23(2), 1981, p. 11-12, retrieved the 1st April 2020 from https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull23-2/23204891014.pdf.
[20] NEA, *Uranium 2018: Resources, Production and Demand*, 2018, p. 104-106.

ii. Construction of nuclear plants

Nuclear plants are investments that require a high capital commitment to be made up front. That is, while the operation costs are relatively low compared to fossil-fuelled power plants, the high initial investments that nuclear power plants demand are an important downside. In the beginning, since nuclear was so tightly related to the military applications of the atom, these costs were generally overseen by the Governments. Yet, since nuclear plant constructions were made available for private investors, the focus on the nuclear power economics has been sharpened. The actual costs of reactors compared to the projected ones does not help either, as they normally escalate as the build-up is taking place.

The cost of power plants is not the only problem with their construction. Most projects experience years long delays (in mid-2019, 59% of the building projects were delayed) and the average construction time of the units has recently been around 10 years. With nuclear power plants taking longer to be built than comparable solar o wind power utilities, the existing fossil-fuelled plants awaiting substitution emit far more CO_2 when nuclear is chosen over renewables: "Stabilizing the climate is urgent, nuclear power is slow"[21].

iii. Proliferation risks

While nuclear energy can be used as a mean to bring cheap power to electricity-impoverished countries, a malicious use of it can bring death and destruction like no other weapon. Pierre Curie had already remarked it in 1904, after the discovery of radium, that it could be "a terrible means of destruction in the hands of great criminals who lead the peoples towards war"[22], but probably never imagined that the danger would evolve into the form of atomic bombs.

Proliferation risks refers to the concern over the construction of nuclear weapons thanks to the spent fuel from nuclear reactors. As stated *supra*, it is possible to

[21] WORLD NUCLEAR INDUSTRY STATUS REPORT, *The World Nuclear Industry Status Report 2019*, 2019, p. 15.

[22] FRANK, I. M., "The importance of ДЕТАНТ. A Soviet Nobel laureate calls on scientists to work for nuclear disarmament", *Bulletin of the Atomic Scientists*, December 1976, p. 35.

obtain plutonium from the nuclear fuel cycle. In fact, the main purpose of nuclear reactors from the beginning was to extract plutonium for their respective nuclear weapons programs.

Under the UN framework, two important instruments have been proposed regarding the matter of nuclear weapons: the *Treaty on the Non-Proliferation of Nuclear Weapons*[23], into force since 1970, and the *Treaty on the Prohibition of Nuclear Weapons*[24], open for signature since 2017. However, the risks that the expansion of nuclear energy pose in terms of proliferation are serious enough to reduce the attraction of nuclear energy[25]. While the plutonium is protected by the intense radioactivity of the spent fuel, the chemical process that is used to separate the plutonium is well known and any country could carry it out to acquire material for several weapons.

iv. Safety concerns

Although actions carried out through the use of nuclear weapons are the most devastating means of war at the current state-of-the-art technology, public opinion towards nuclear energy still focuses in the accident concerns in nuclear power plants, which receive more attention than the nuclear proliferation risks. The most remarkable safety concern that comes with nuclear power is the possibility that a nuclear power plant could accidentally release radiation into the environment, but they are also a risk in terms that they can become potential targets for terrorist attacks.

Even though there have not been many important accidents through the history of nuclear plants, a few of them have been very serious. An accident that could occur in a nuclear plant could be a meltdown of the reactor's core, due to severe overheating, which could make the plant to release radioactivity into the

[23] Treaty on the Non-Proliferation of Nuclear Weapons (NPT), of 12th June 1968, in force from 1970 and ratified by a total of 191 States, including the five nuclear-weapon States (China, France, Russia, United Kingdom and United States).
[24] Treaty on the Prohibition of Nuclear Weapons (TPNW) of 7th July 2017, not yet in force because it has only been ratified by 36 States.
[25] MIT ENERGY INITIATIVE, *The Future of Nuclear Power: An Interdisciplinary MIT Study*, MIT, 2003, p. 68.

environment. The risk of this happening is very low, but its impact would be so large, it is able to completely change the public perception of nuclear power.

Fatal errors that lead to incidents and accidents in nuclear plants are mostly due to human and technical mistakes, but nuclear energy can be safe. Yet, it is important to remark that one of the highest risks when it comes to this is the pressure put by private operators to maximize profits over safety, as they can be "more concerned with maximizing plant output and less willing to close plants for safety inspections and corrective actions where necessary", even if a high level of safety is economically beneficial, as accident costs can be ravaging[26].

v. Nuclear waste disposal

Nuclear fission is a great way to create big amounts of energy because it is very powerful. productive and has no direct carbon emissions. Nevertheless, it comes with a critical downside: the waste you leave behind after starting your nuclear reaction.

Nuclear waste is "the longest-lived, most highly radioactive, and most technologically challenging of the waste streams generated by the nuclear industry"[27]. They are hazardous substances for human beings and the environment because they are highly radioactive, and some of them will remain like this for thousands of years. It is therefore of great importance to manage this waste effectively to be contained for long periods of time.

Since the early years of the nuclear industry, the management of nuclear waste has been a challenge that countries have had to face, and no perfect solutions have been found yet, especially to deal with the high-level radioactive waste. Out of all the nuclear waste that is generated, it is the smallest part, yet the most dangerous.

Due to the enormous and complex issue they signify for the implementation of nuclear energy plants, nuclear waste will be specifically dealt with *infra*, where we will examine the concept of radioactive waste, how it is produced, the types of waste

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[26] MIT ENERGY INITIATIVE, *The Future of Nuclear Power…, op. cit.*, p. 47.
[27] *Ibid*, p. 53.

and the solutions that radioactive waste management offers in terms of its disposal, as well as the difficulties those solutions are facing in terms of their implementation.

D. The issue of radioactive waste

The concept of *nuclear waste* is used to refer to the series of by-products that arise from the electricity generation process that takes place in nuclear plants. It is part of a wider concept, *radioactive waste*, which also accounts for the waste that is produced out of nuclear plants but is still radioactive and requires especial management. What needs to be taken into account is that nuclear waste suffers the pressure of a double stigma: it is waste, and it is radioactive due to its nuclear origin. Consequently, it is something that members of a society want to get rid of, but given that this waste is radioactive, it needs to be disposed of in a particular way for safety reasons[28].

Radioactive waste arises from the nuclear fuel cycle operations, but also from the extraction of materials needed to power nuclear plants, as it is not a homogenous type of waste. For example, spent nuclear fuel is considered a type of radioactive waste, but so is the contaminated protection equipment for clothing and shoes that is used in nuclear plants. However, despite the differences in the physical manifestation of this type of waste, waste from nuclear energy production, because of the radioactivity contained in it, is very hazardous for human beings and the biosphere in general.

Just like the radioactive waste is a heterogeneous group of matter considered as waste, the sources, or activities in which this waste is generated, also vary. Radioactive waste owned by countries come from different types of activities. The most important is the nuclear power-related, generated in the process of mining for uranium (tailings), uranium enrichment (depleted uranium), electricity generation (spent fuel when it is not reprocessed), reprocessing of spent fuel (fission products) or decommissioning of nuclear plants (steel components). Some countries also must

[28] BERGMANS, A., *et al.*, *Wanting the Unwanted: Effects of Public and Stakeholder Involvement in the Long-term Management of Radioactive Waste and the Siting of Repository Facilities*, CARL Project, 2008, p. 9.

deal with liabilities of what is called *legacy waste*, from their early weapon programmes' days. Additionally, countries also generate radioactive waste in other activities not related to nuclear power, such as laboratory research or nuclear medicine at hospitals.

The main issue with this waste is that it is radioactive, but not all waste is equally radioactive. It depends on the activity concentration in the matter. Radioactivity is measured in disintegrations per second and its unit of measure is the *Becquerel* (Bq). To classify the waste, an activity concentration criterion is used, such as Bq/g or TBq/m^3. This allows us to classify the waste to design the disposal methods more efficiently. For the disposal, though, it is also noteworthy to consider the half-lives of the waste's radionuclides. Radionuclides are unstable elements we find in the waste that, due to the instability of its core, release excess energy by different types of radioactive decay. When they decay, these radionuclides emit radiation harmful for humans and the environment. In nuclear waste, we will find radionuclides with half-lives of a few days (*i.e.* Iodine-131) or millions of years (*i.e.* Iodine-129). Therefore, the half-life of the radionuclides found in the waste will also differentiate certain wastes from others.

i. Types of radioactive waste

The heterogeneity of what we refer to *radioactive waste* has been drawn to attention *supra*. It stems from the fact that it is produced by different sources and comes in different forms. Therefore, it can be classified attending many criteria, such as the following.

- *By origin*: uranium mining, uranium enrichment, electricity generation in civil nuclear power plants, fuel reprocessing, nuclear plant facilities decommission, legacy waste or non-nuclear power waste from hospitals or research at laboratories.
- *By physical state of manifestation*: liquid, gas or solid state.
- *By its properties*: compactable, burnable, reprocessable, among others.

Furthermore, not only the classification of nuclear waste can depend on the criteria chosen, but also on the legal framework of the country in which we are in. Nonetheless, the IAEA has contributed to define the types of radioactive waste with its *Safety Standards*. In its safety guide *Classification of radioactive waste*[29], the IAEA defines six different types of waste considering its activity levels and the half-lives of its radionuclides.

- *Exempt waste***.** Due to its small concentration of radionuclides, exempt waste is cleared from regulatory control. It does not require any especial provisions to ensure radiation protection and can therefore be disposed of in conventional landfills or recycled at will.
- *Very short-lived waste***.** Very shorted lived waste only contains radionuclides with very short half-lives. Therefore, it cannot be directly disposed of as conventional waste, but it can after it has been stored until the radioactivity has decayed beneath the clearance levels.
- *Very low-level waste***.** Such waste presents above clearance levels of radioactivity, so it cannot be considered exempt waste, but neither requires a high level of containment and isolation. For that reason, it can be disposed of with a limited regulatory control.
- *Low-level waste***.** Low level waste is also above clearance levels, but has limited amounts of long-lived radionuclides, so it is more demanding than very low-level waste in terms of containment and isolation. This can take up to a few hundred years, but afterwards, the low-level waste can be disposed of in engineered near surface facilities.
- *Intermediate-level waste***.** Because it contains some long-lived radionuclides, it requires a greater degree of containment and isolation and it is not suitable for near surface. Instead, it requires disposal at depths on the order of tens to hundreds of metres.
- *High-level waste***.** It contains such large concentrations of short- and long-lived radionuclides, that a greater level of containment and isolation is

[29] IAEA, *Classification of Radioactive Waste*, IAEA Safety Standards for protecting people and the environment, General Safety Guide No. GSG-1, 2009, p. 5-6, retrieved the 7th April 2020 from https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1419_web.pdf.

required, especially to ensure long term safety. It is the most troublesome kind of waste, even though it is not the most abundant. That is because, while high-level waste only represents 3% of the total stock of radioactive waste, it concentrates around 99,8% of the total radioactivity found in the stocks[30].

This is a widely accepted classification of nuclear waste, but its importance relies on the fact that it is proposed by the IAEA and their safety guides. That means, even though the IAEA is not qualified to impose this classification to its Member States, countries usually follow it when establishing their radioactive waste disposal strategy. In spite of this, the boundaries between classes are general and detailed quantitative boundaries may be developed by national regulations[31].

ii. Disposal methods

Radioactive waste, as it has been stated in the previous pages, is still currently the most important downside of nuclear energy. Members of the industry, as well as governments and scientists, are still trying to find out a way to manage nuclear waste safely. In the year 2020, many decades after the start of operations in the first commercial nuclear reactor, there is still not a single permanent repository for high-level radioactive waste. The disposal of this type of waste does not take place in the immediate future after its generation, because it has to be treated and stored first. In fact, this might not take place after fifty or sixty years, but nowadays it is time to take some action, as we will need to deal soon with the waste generated at the beginning of our nuclear days.

This was not a primarily issue during the early years of the nuclear power industry though. As countries were more focused on the development of their nuclear weapons programmes, the matter of nuclear waste was easily resolved. It is believed

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[30] BALAGUER, F., "Les déchets nucléaires, ou les cailloux dans la chaussure de l'économie circulaire", *Droit et Ville*, 87, 2019/1, p. 234.

[31] IAEA, *Classification of Radioactive Waste*, *op. cit.*, p. 5.

that tonnes of radioactive waste have been dumped in the sea by countries such as the United Kingdom, the US, or the former Soviet Union.

This method of disposal for radioactive waste had soon to be reconsidered when concerns over the pollution of seas and oceans started to raise during the 1970s. An example was the appearance in 1972 of the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*[32], also known as the *London Dumping Convention*. It is considered to be one of the first conventions with a global projection regarding the protection of the marine environment from human activities. Its Article IV states that "in accordance with the provisions of this Convention Contracting Parties shall prohibit the dumping of any wastes or other matter in whatever form or condition except as otherwise specified below: (a) the dumping of wastes or other matter listed in Annex I is prohibited". Number 6 in Annex I is "radioactive wastes or other radioactive matter".

Since then, investments on research aimed at finding new ways to dispose of radioactive waste effectively have been made. Yet, no satisfactory method of disposal for high-level waste has been found. *Infra*, we will go through some of the methods that are currently being used to dispose radioactive waste, although they will be referred to all kinds of waste.

What needs to be bear in mind while going through the different disposal methods proposed to deal with radioactive waste is that the period that is considered in these cases can range from a few thousands of years to nearly a million years, which is a time frame hard to imagine. However, it needs to be considered due to the half-life of the radioactive isotopes found in it. For example, we can find Iodine-129, with a half-life of 15.7 million years, or Technetium-99, with a half-life of 211,000 years. Hence the reason why some of the following methods are, when permitted, not implemented, resulting from the lack of practical studies.

[32] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 13th November 1972, in force from 1977. Currently, 87 States are parties of the Convention.

a) Deep geological repositories (DGR)

While low-level waste can be disposed of in near-surface repositories similar to generic landfills, that is not the case with high-level waste. Geological disposal of radioactive waste consists of the placement of the high-level waste and spent nuclear fuel in safe repositories a several hundred metres underground. That happens after the interim storage of the waste in cooling pools placed near the reactors takes place, a storage that can last up to a few decades. During that time, the radioactivity levels start to decay and only a few percent of the initial amount remains[33], but the waste still needs a special method of disposal, for which DGRs are suitable. Countries that use nuclear power as a mean of generation of electricity have been researching on geological disposal solutions and it is widely accepted as a safe and environmentally sound solution for the kind of wastes mentioned above.

The safety of these repositories stems from the fact that they are protected by a multiple system of barriers, some of them as part of the engineering design of the repository, but also from the geological conditions of the environment chosen to locate the repository: the waste form, the waste container, buffer materials, backfill, sealing systems and geology[34]. Therefore, when a barrier fails to isolate due to any kind of technical issue, a leakage into the environment is not immediately produced. And even when the engineered barriers degrade by interaction with geological elements, such as groundwaters, which is a reasonable scenario over long periods of time, this might take thousands of years and it will be long after the radioactivity of the matter has naturally decayed to less harmful levels. Given this circumstance, even in that future, radioactivity that is released will not cause health risks to future human generations.

Internationally, this is the most favoured method of disposal for radioactive waste and countries have decided to tackle the waste issue of nuclear energy with this strategy in the long-term. Nonetheless, despite the international scientific consensus

[33] HEDIN, A., *Spent nuclear fuel – how dangerous is it? A report from the project Description of risk*, Swedish Nuclear Fuel and Waste Management Co., T. Report 97-13, March 1997, p. vi.
[34] MORRIS, K., *et al.*, “Geodisposal of Higher Activity Wastes”, in HARRISON, R. M., *et al.*, *Nuclear Power…, op. cit.,* p. 132-134.

on this being the best solution, not a single deep geological repository for high-level waste is operational nowadays. Engineering is not the main challenge for their implementation though, but to convince a local community to allow the construction of a repository nearby. After all, humans have dug deeper coal mines, hundreds of metres below a hypothetical DGR. Nevertheless, the NIMBY (*not in my back yard*) movement has been strong all over the world and has prevented the construction of DGR in different occasions[35].

Finland is the only country that has built a repository up to day, the *Onkalo spent nuclear fuel repository* in *Olkiluoto*, expected to start operations over the next decade[36], and the second most advanced country in terms of DGR is Sweden, which is still going through the process of applicating for a license to build the nuclear waste repository[37].

b) Deep borehole disposal (DBD)

Despite the difficulties that deep geological disposal facilities are facing in their implementation, there are advocates for the deep borehole disposal of radioactive waste. Instead of focusing on mined underground caverns a few hundred metres deep, DBD advocates for the drill of very deep holes on the ground, several kilometres long, in which the radioactive waste would be put and would be covered with rock and cement[38].

This method of disposal presents many benefits. The deep borehole concept offers advantages over the geological repository concept in terms of location, as it is not significant to choose where to drill these holes, but also as a more-secure, cost-effective and environmentally sound method compared to mined repositories. While a number of engineering challenges still endure, especially on the limitations on the width of these holes, because so far we have not been able to drill holes with

[35] BERGMANS, A., *et al.*, *Wanting the Unwanted…*, *op. cit.*, p. 9.
[36] MATTILA, J., *et al.*, "Stress-controlled fluid flow in fractures at the site of a potential nuclear waste repository, Finland", *Geology*, 40 (4), 2012, p. 299.
[37] BALDWIN, T., *et al.*, *Geological Disposal Options for High-Level Waste and Spent Fuel*, Report for the UK Nuclear Decommissioning Authority, January 2008, p. 2-3.
[38] ARNOLD, B.W., *et al.*, *Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste*, Sandia National Laboratories, October 2011, p. 12-13.

diameters as wide as large radioactive waste containers aimed for disposal at DGR, deep borehole disposal could still be used for the disposal of certain types of radioactive waste, it being an easy and cheap method to carry out[39].

c) Storage at above ground levels

An alternative to underground disposal is disposal at above-ground levels. It is, however, more accurate to refer to this method as a storage procedure. Therefore, we need to difference between the concepts of *disposal versus storage*. While the former usually takes place to get rid of the waste for good, the latter refers to the maintenance of the waste in a manner that allows retrieval in the future, while ensuring that in the meantime it is isolated from the external environment[40]. For that reason, when we talk about above ground disposal, it is more correct to refer to it as storage, as the waste can be retrieved at will.

One technique to store used nuclear fuel is dry cask storages. In these, spent fuel that has already been cooled in spent fuel pools for at least a year and up to a decade, which also allows for the radioactivity levels to decay, is removed from these pools and is placed into dry casks, which are safe for people and the environment. They are especially designed to contain the radiation and control the heat, as well as resist extreme conditions, such as earthquakes or extreme temperatures, to prevent the release of radioactivity in the environment[41].

They typically look like concrete vaults from the outside because it is the concrete that provides the radiation shield, but the spent fuel is placed inside numerous layers. It is worth noticing that this cannot be considered a long-term solution for the disposal of nuclear waste but allows the retrieval of that used fuel for its reprocessing if needed.

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[39] BESWICK, J. A., *et al.*, "Deep borehole disposal of nuclear waste: Engineering challenges", *Proceedings of the Institution of Civil Engineers – Energy*, 167(EN2), 2012, p. 47.

[40] WORLD NUCLEAR ASSOCIATION, *Radioactive Waste Management*, retrieved the 9th April 2020 from https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx.

[41] US NUCLEAR REGULATORY COMMISSION, *Backgrounder: Dry Cask Storage of Spent Nuclear Fuel*, U. S. NRC, October 2016, p.1.

However, dry cask storage is meant for storing high-level waste at above-ground levels, but there are also other means of disposal for radioactive waste underground, but at a near-surface depth. Nevertheless, these are only suitable disposal methods for very low- and low-level radioactive waste.

d) Nuclear reprocessing

Nuclear reprocessing takes place in closed fuel cycles, opposite to open fuel cycles. On one hand, in open fuel cycles, the spent nuclear fuel is discharged from the reactor to be treated as waste. Obviously, this is high-level radioactive waste that needs to be disposed of somehow (see deep geological disposal or deep borehole disposal) with the problems this poses.

On the other hand, in closed fuel cycles, the spent fuel that is discharged from the reactor is reprocessed. That is because in it, there is plutonium and uranium suitable for manufacturing mixed oxide fuel (MOX), which can be recycled back into the reactor. Some of the reprocessed fuel will still be considered HLW, but the amount of waste produced will significantly be reduced. For that reason, nuclear reprocessing is, to some extent, a method of disposal. However, the remaining waste still needs to be disposed of according to its category of HLW and, therefore, nuclear reprocessing cannot be considered as a long-term method of disposal of nuclear waste.

There are other reasons for which closed fuel cycles, and therefore, recycling of spent fuel is not considered in many countries. There are cost reasons, *ie.* reprocessing of spent fuel takes place in reprocessing plants, which are also considerable investments. But open fuel cycles are also favoured in non-proliferation grounds, as there is no separation of plutonium from the spent fuel and proliferation risks are under control[42].

e) Other methods

Research on the disposal of nuclear waste has also considered many other methods, but most have been rejected due to their impracticability, expensiveness, or

[42] MIT ENERGY INITIATIVE, *The Future of Nuclear Power…*, *op. cit.*, p. 29-31.

unacceptability from an ecological point of view. However, they are still worth mentioning.

Nuclear waste disposal in the outer space was seen as a possible option in the beginning and even the National Aeronautics and Space Administration (NASA) draw a technical paper in 1978 that studied its viability[43], analysing aspects such as the space options, the packaging that would be needed or the safety and space transportation system requirements. However, although disposal could be feasible from a technical point of view, according to the NASA, its constraints have not made it an attractive option.

Disposal of radioactive waste in ice sheets has also been considered, as early as in the 1950s. Scientists, such as K. Philberth, have proposed ways to dispose it under the Earth's surface, either on the ice of Antarctica or Greenland, affirming that even "the most upsetting natural ice-sheet instabilities and/or climatic changes could not cause radioactive contamination"[44]. It is, however, a questionable option from an ecological perspective, but also legal, as the disposal of radioactive waste in Antarctica is explicitly prohibited by Article V of the Antarctic Treaty, which states that "any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited"[45].

Another method that has been proposed with doubtful ecological implications is the dumping of nuclear waste in isolated islands. It is a method that has been used in the past, for example, by the US, in the Marshall Islands[46]. The US carried out several nuclear tests in the Runit Island after the Second World War and build a concrete dome to encapsulate the radioactive waste produced, including fatal amounts of plutonium. It is not, however, a satisfactory mean of disposal, as locals

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[43] BURNS, R.E., *et al.*, *Nuclear Waste Disposal in Space*, NASA Technical Paper 1225, May 1978, p. 1-3, retrieved the 10th April 2020 from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19780015628.pdf.

[44] PHILBERTH, K., "The Disposal of Radioactive Waste in Ice Sheets", *Journal of Glaciology*, 19(81), 1977, p. 607.

[45] The Antarctic Treaty, of 1st December 1959, in force from 1961 and ratified by a total of 54 States.

[46] DAVISSON, M. L., "Radioactive waste buried beneath Runit Dome on Enewetak Atoll, Marshall Islands", *International Journal of Environment and Pollution*, 49(3/4), 2012, p. 161.

are seeing how the effects of climate change in the rising of the sea levels is making the dome flush out radioactive water with the tide changes, contaminating the nearby coral reefs.

Additional methods have been suggested, such as the disposal of waste in trenches found in the oceans. The idea would be that, due to the process of subduction tectonic plates go through, the barrels of high-level radioactive waste could be engulfed by the hot mantle below. Nevertheless, it is an option that has been dismissed. It stems from the fact that this process of subduction is geologically slow and, therefore, these barrels would still be available for retrieval for thousands of years, while the uranium and plutonium still present high levels of radioactivity. But even so, the disposal would still take place in the oceans, which is banned by the *London Dumping Convention*.

III. International legal framework of radioactive waste disposal

As it has been seen *supra*, in the early nuclear years, the downsides of nuclear energy were not of special concern for nations worldwide. For that reason, the risks were not really considered when drafting the internal nuclear policies. Under the IAEA, it was believed that the risks in terms of human lives and the environment could safely be managed through intergovernmental collaboration and cooperation on safety matters.

The first concerns over nuclear power were not about incidents or waste, but over proliferation risks, especially beyond the five Permanent Members of the UN Security Council. In this field, under the IAEA framework, the *Nuclear Non-Proliferation Treaty* was adopted in 1968, to avoid the spread of nuclear weapons, although it did not reduce the existing nuclear weapons arsenals[47] and nuclear weapon testing continued to being carried out by the nuclear weapons powers, against the commitments made in 1963 by the *Partial Test Ban Treaty*[48], which banned nuclear weapon testing in the atmosphere, outer space and under water. In 1996, the *Comprehensive Nuclear-Test-Ban Treaty*[49] was adopted to ban nuclear testing completely, although it has not entered into force yet due to specific nations, such as the United States or China, not ratifying it[50].

Environmental concerns were not a priority until the increasing popularity of nuclear power plants as part of the response to the 1970s oil crisis brought to light the problems of radioactivity emissions and nuclear waste disposal. In this field, one of the earliest legal instruments was the previously mentioned *London Dumping Convention*, that banned ocean disposal of nuclear waste[51].

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[47] BIRNIE, P., *et al.*, *International Law and the Environment*, 3rd Edition, OUP, 2009, p. 490.

[48] Treaty banning nuclear weapon tests in the atmosphere, in outer space and under water (Partial Test Ban Treaty) of 5th August 1963, in force from 1963 and ratified by a total of 126 States.

[49] Comprehensive Nuclear-Test-Ban Treaty of 10th December 1996, yet to get into force.

[50] BIRNIE, P. *et al.*, *International Law and the Environment*, *op. cit.*, p. 490-491.

[51] *Ibid*, p. 491.

In the 1980s, the environmental concerns transferred to the accident risks. Especially after *Chernobyl*, international control of safety matters was prioritised, as the world started to split between detractors of nuclear energy and firm believers of international cooperation to contain the risks of nuclear power. The latter could be found in the instruments adopted[52].

A. Universal framework

i. Instruments adopted by the IAEA

Under the IAEA framework, several international conventions have been adopted in the field of nuclear power. Especially, they have addressed the safety[53], emergency[54] and security[55] issues. It is under the *safety* category that we find the reference to radioactive waste.

IAEA Member States adopted the *Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management* (*Joint Convention*) in 1997[56]. It is considered the first international legal instrument to address the issue of spent fuel and radioactive waste management. The main objectives of the Convention are "(i) to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international co-operation […]; (ii) to ensure that during all stages of spent fuel and radioactive waste management there are effective defences against potential hazards […] so that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations;

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[52] BIRNIE, P. *et al.*, *International Law and the Environment*, *op. cit.*, p. 492.

[53] See the Convention on Nuclear Safety of 17th June 1994, in force from 1996, or the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 5th September 1997, in force from 2001.

[54] See the Convention on Early Notification of a Nuclear Accident of 26th September 1986, in force from 1986, or the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency of 26th September 1986, in force from 1987.

[55] See the Convention on the Physical Protection of Nuclear Material of 26th October 1979, in force from 1987.

[56] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 5th September 1997, in force from 2001 and ratified by a total of 76 States.

[and to] (iii) to prevent accidents with radiological consequences and to mitigate their consequences […]" (Article 1).

According to Article 3, the scope of application of the Convention is spent fuel management and radioactive waste disposal from civilian nuclear reactors and from civilian applications. Therefore, waste generated under military programmes is excluded, unless an extension of the scope is accepted by the Contracting Party, or the waste is transferred to permanent civilian control. Furthermore, reprocessing of spent fuel is only included if the relevant party so declares[57].

The importance of the *Joint Convention* in terms of fulfilling these objectives relies, on one hand, in the establishment of fundamental safety principles in the different areas of spent fuel and radioactive waste management. On the other hand, it does also create a peer-review procedure, detailed in its Chapter 6 of *Meetings of the Contracting Parties*, for which these Parties commit to "submit a national report to each review meeting of Contracting Parties" (Article 32-1), in which the steps taken to implement the obligations listed in the Convention will be detailed, as well as the reporting requirements listed in Article 32. These meetings are held with intervals of no longer of three-years, as stated in Article 30-2 (i).

The main provisions of the Convention in terms of general safety obligations are based largely on the IAEA 1995 *Principles of Radioactive Waste*. For that reason, the *Joint Convention* is considered to have given these IAEA safety standards a binding treaty status. Therefore, the Convention does not create a new law but rather reinforce the status of previously acknowledged principles.

The same happened with the main provisions of the IAEA 1990 *Code of Practice on the International Transboundary Movement of Radioactive Waste*. Those soft-law recommendations were largely based on the *Basel Convention of the Control of Transboundary Movements of Hazardous Wastes and their Disposal* of 1989[58], from which radioactive waste was explicitly excluded by Article 1-3. The

[57] BIRNIE, P. *et al.*, *International Law and the Environment*, *op. cit.*, p. 503.

[58] Basel Convention of the Control of Transboundary Movements of Hazardous Wastes and their Disposal of 22nd March 1989, in force from 5th May 1992 and ratified by a total of 187 States.

Convention gave binding force to this Code of Practice through the inclusion of Article 27 of the *Joint Convention,* that regulates the transboundary movement of radioactive waste.

However, it also worth remarking that the objective stated in Article 1 (ii) is considered the strongest provision on intergenerational equality laid out in any environmental treaty, and consequently, this Convention is important, not only in terms of nuclear law, but also environmental law[59].

As seen *supra*, the *Joint Convention* is an instrument with legal binding force that affects radioactive waste management. Nonetheless, the IAEA is entitled to establish and adopt "standards of safety for protection of health and minimization of danger to life and property (including such standards for labour conditions)" (IAEA Statute, Article III.A.6) in collaboration with other UN agencies. These standards include regulations, rules, requirements, codes of practice and guides, covering subjects such as radiation protection, transport and handling of radioactive materials, nuclear installations safety, but also radioactive waste disposal[60].

The IAEA Statute does not confer any binding force to these health and safety standards. In fact, Member States are not required to comply with them. Yet, they have contributed to the control of nuclear energy risks. That is because these documents, although their adoption can be controversial –as they are sometimes adopted by the IAEA Board of Governors, and not the General Conference in which all Member States are represented–, are drafted in cooperation with specialist bodies and reflect a large measure of expert and technical consensus, after Governments are consulted during the formulation stage. Therefore, these standards have resulted in a great degree of harmonisation among the international community[61].

Some of the IAEA Safety Standards relevant in the topic of radioactive waste are the *Safety Guide No. WS-G-6.1 on the Storage of Radioactive Waste* (2006), the

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[59] BIRNIE, P., *et al*., *International Law and the Environment*, *op. cit.*, p. 504.
[60] *Ibid*, p. 494.
[61] *Ibid*, p. 496.

Specific Safety Guide No. SSG-15 on the Storage of Spent Nuclear Fuel (2012), the *General Safety Guide GSG-1 on the Classification of Radioactive Waste* (2009), the *Specific Safety Guide No. SSG-47 on the Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities* (2018), among others. They are framed under the Radioactive Waste Safety Standards (RASWASS) Programme, aimed at establishing a "coherent and comprehensive set of principles, requirements and recommendations for the safe management of radioactive waste and formulating the guidelines necessary for their application"[62].

ii. Other instruments

Under the framework of the Organisation for Economic Co-operation and Development (OECD), the Nuclear Energy Agency (NEA) also has a similar role as the IAEA and standards in waste management have been adopted in collaboration among with IAEA, but like the standards of the IAEA, the NEA has no power to compel the compliance of its Member States[63].

Radioactive waste is also an issue that is brough up, not exactly within the IAEA framework, but under the UN umbrella. For example, during the 74th Period of Sessions of the UNGA, it adopted a series of resolutions, after the recommendations of the First Committee[64], under the item "General and complete disarmament". One of those resolutions is entitled *Prohibition of the dumping of radioactive wastes*, a draft resolution which was submitted to the Committee by Nigeria, on behalf of the UN Member States that are members of the Group of African States.

The fact that it was submitted by the African States is not trivial. It responds to the fear that Africa could become the world's landfill of radioactive waste, after some of its countries, such as Ghana or the same Nigeria, have already become the

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[62] VOVK, I., *IAEA Programme for Radioactive Waste Safety Standards*, IAEA, Regional seminar, 1998, p. 44.
[63] BIRNIE, P., *et al.*, *International Law and the Environment*, op. cit., p. 507.
[64] UNGA, *General and complete disarmament: Report of the First Committee*, doc. A/74/368, 20th November 2019.

unofficial landfills of richer European countries' electronic waste[65]. It would only be natural to think radioactive waste could be dumped next.

African countries are already protected by the *Bamako Convention* (1991), a treaty by African nations that prohibits the import into the continent of any hazardous waste, including radioactive waste. As stated by the Article 2.2, "Wastes which, as a result of being radioactive, are subject to any international control systems, including international instruments, applying specifically to radioactive materials, are included in the scope of this Convention". However, it is interesting to reinforce the idea through the UNGA.

The resolution adopted by the UNGA, *Prohibition of the dumping of radioactive wastes*[66], addressed the international community with some interesting statements. Among others, it "calls upon all States to take appropriate measures with a view to preventing any dumping of nuclear or radioactive wastes that would infringe upon the sovereignty of States". It "expresses grave concern regarding any use of nuclear wastes that would constitute radiological warfare and have grave implications for the national security of all States" and, to promote the implementation of the paragraph 76 of the Final Document of the Tenth Special Session of the General Assembly, on the topic of disarmament, which states that "A convention should be concluded prohibiting the development, production, stockpiling and use of radiological weapons", the resolution "requests the Conference on Disarmament to take into account, in any negotiations for a convention on the prohibition of radiological weapons, radioactive wastes as part of the scope of such a convention". Besides this, the resolution also appeals to the non-Contracting Parties of the *Joint Convention* to become parties of it as soon as possible.

That being an example of a resolution that deals with radioactive waste withing the UN, it must be noted that radioactive waste has also been considered in other UN documents, such as the *United Nations Conference on Environment &*

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[65] PLATFORM FOR ACCELERATING THE CIRCULAR ECONOMY, *A New Circular Vision for Electronics. Time for a Global Reboot*, World Economic Forum, January 2019, p. 14.
[66] UNGA, Resolution 74/58, *Prohibition of the dumping of radioactive wastes*, doc. A/RES/74/58, 12th December 2019.

Development[67], celebrated in Rio de Janeiro, in June 1992, commonly known as the *Agenda 21*. Its Chapter 22 deals with the "Safe and Environmentally Sound Management of Radioactive Wastes" and sets different actions for States to accomplish through international cooperation and coordination, the objective of which is ensuring that radioactive waste is "safely managed, transported, stored and disposed of, with a view to protecting human health and the environment, within a wider framework of an interactive and integrated approach to radioactive waste management and safety" (par. 22.3).

Taking into account this is a document of 1992, it is understandable that some of its proposals were subsequently introduced in the 1997 *Joint Convention* (*i.e.* promoting policies to minimize and limit, where appropriate, the generation of radioactive wastes and provide for their safe processing, conditioning, transportation and disposal). However, it is surprising how it was unconfident about which was the best approach to radioactive waste in the sea, as while it was encouraging to replace the then-currently-in-force voluntary moratorium on disposal of low-level waste at sea by a ban, it only *recommended* not to promote or allow the disposal of any kind of radioactive waste near the sea unless there was scientific evidence on the lack of risks.

When addressing the international framework in which nuclear energy and radioactive waste management are found, it must be linked with the UNGA resolution 70/1, "Transforming our world: the 2030 Agenda for Sustainable Development"[68], which lays down "a plan of action for people, planet and prosperity". The plan is firmed up with the establishment of seventeen *Sustainable Development Goals* (SDG) and one-hundred sixty-nine specific targets to achieve sustainable development in all its three dimensions: the economic, the social and the environmental. They aim to build on the *Millennium Development Goals*

[67] UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (UNCED), *Agenda 21: programme of action for sustainable development*, 1992, p. 267-269.
[68] UNGA, Resolution 70/1, *Transforming our world: the 2030 Agenda for Sustainable Development*, doc. A/RES/70/1, 25th September 2015.

(MDG)[69] and achieve what they could not in the years going from 2000 to 2015, in the years that go from 2016 to 2030.

While the seventeen SDG cover such different fields of sustainability[70] in the development of nations –naming some, "No poverty" (Goal 1), "Gender Equality" (Goal 5), "Responsible Consumption and production" (Goal 12)–, the one that should affect the radioactive waste management policies is Goal 7, regarding "Affordable and clean energy". Its objective is to guarantee access to affordable, reliable, sustainable and modern energy for all through ensuring "universal access to affordable, reliable and modern energy services" (7.1), increasing "the share of renewable energy in the global energy mix" (7.2) and doubling "the global rate of improvement in energy efficiency" (7.3) by the year 2030.

Goal 7 is capable to affect, from one side, nuclear power, as it calls for promoting the investment in clean energy technology, and we have seen it is a carbon-free energy generation technology. It also would be encouraged from the perspective of Goal 12, related to taking "urgent action to combat climate change and its impacts". On the other side, if the non-contaminant characteristic is empathised from a broader perspective, it would talk out of the nuclearization of energy mixes for as long as there is no method of disposal that keeps these hazardous types of waste from affecting human health and the environment.

In any case and to draw some ideas, in response to the encouragement to all Member States to develop national strategic plans to achieve the implementation of the Agenda 2030, as an example, Spain published its "*Plan de Acción para la Implementación de la Agenda 2030: Hacia una Estrategia Española de Desarrollo Sostenible*"[71], and regarding the strategy laid out in connection with Goal 7, no further reference to nuclear energy and waste is made.

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69 UNGA, Resolution 55/2, *United Nations Millennium Declaration*, doc. A/RES/55/2, 18th September 2000.

70 DÍAZ, C. M., "Los objetivos de desarrollo sostenible: un principio de naturaleza incierta y varias dimensiones fragmentadas", AEDI, 32, 2016, p. 16.

71 MINISTERIO DE ASUNTOS EXTERIORES, *Plan de Acción para la Implementación de la Agenda 2030: Hacia una Estrategia Española de Desarrollo Sostenible*, 2018, p. 36-37.

B. European Union/EURATOM framework

While radioactive waste management regulations can be studied from the perspectives of many regions (American, Asian, African, etc.), our study will be focused on the European perspective for several reasons. Firstly, because of the relevance of nuclear power in European countries, and therefore, of generation of radioactive waste. Secondly, because the objective of this research is to ultimately compare the legal frameworks of France and Spain regarding the disposal of their radioactive waste, thus it is interesting to know a bit more about the European frameworks, which both countries will have their regulations influenced from.

As we have seen *supra*, one of the two treaties signed in Rome in 1957 was the *EURATOM Treaty*. The main objective of the Organisation was to create an adequate environment for the establishment and growth of the nuclear industry. But in order to achieve this, Article 2 (b) of the Treaty recognises that the Community can "establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied".

Within our area of interest, disposal of radioactive waste is already mentioned in the *EURATOM Treaty*, as Article 37 establishes that "each Member State shall provide the Commission with such general data relating to any plan for the disposal of radioactive waste in whatever form will make it possible to determine whether the implementation of such plan is liable to result in the radioactive contamination of the water, soil or airspace of another Member State […]".

An important difference between the EURATOM and the IAEA relies on the fact that those "*uniform safety standards*" are laid out in the form of directives, not safety standards as recommendations. Therefore, Member States are required to implement these safety directives at a national level and ensure their enforcement.

In terms of radioactive waste management, it is a widely accepted principle that the management of spent fuel and radioactive waste is governed by national legislations, as well as international conventions, like the *Joint Convention*. However, the principles contained in those instruments are supplemented by a

Directive in the EU Member States, providing binding force to those principles. The *Council Directive 2011/70/EURATOM, of 19 July 2011, establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste* aims at ensuring a high level of safety, at attaining a great level of transparency in terms of public information and participation and at avoiding the imposition of undue burdens on future generations through responsible and safe management of spent fuel and radioactive waste (Article 1).

Some of the general principles contained in the Directive that are of interest for us are the following: that each State has ultimate responsibility for management of the spent fuel and radioactive waste generated in it (Article 4.1); that the generation of radioactive waste shall be kept to the minimum and the costs of the management borne by those who generated them (Article 4.3); that radioactive waste shall be disposed of in the Member State in which it was generated, unless there is an agreement with another Member State or a third country to use a disposal facility in one of them, in which case certain standards will have to be complied to (Article 4.4); that Member States shall establish and maintain a national legislative, regulatory and organisational framework for the management of nuclear waste (Article 5.1); or that each Member State must establish a competent regulatory authority in this field (Article 6.1).

Just like the *Joint Convention* under the IAEA framework, this Directive also drafts a reporting process for peer review. Member States must commit to submit reports on the implementation of the Directive. The first one was by August 2015, but the following must be submitted every three years thereafter (Article 14).

IV. Comparative analysis on disposal solutions for radioactive waste in France and Spain

The operation of nuclear plants in nuclear power countries is carried out under a strict legal framework to reassure the correct operation of them, as well as achieving the highest levels of safety to prevent nuclear incidents and accidents, while guaranteeing the workforce involved is protected from radiation emissions and other occupational accidents. The main aspect is, therefore, *safety*. Under this concept, nuclear waste management regulations come into being.

In fact, the establishment of a nuclear waste management legal framework is recognised in the 1997 *Joint Convention*, which states in its Article 19(1): "Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management". This includes regulations on the transport and location, design, and operation of the storage facilities in which the radioactive waste will be disposed of for good.

Two national regulatory frameworks on nuclear waste management will be examined *infra*: the French and the Spanish. A comparative approach, while studying the deficiencies and difficulties these two countries face when managing their nuclear waste, can be interesting to retrieve new ideas, especially when it comes to form an opinion on nuclear power as an electricity generation method, which in turn is such a bipolarised subject.

While bearing in mind that the regulations might not be significantly different, as both countries have ratified the IAEA Joint Convention[72], it is also important to remember that both France and Spain, as Member States of the EU, are obliged to comply with the Directive 2011/70/EURATOM[73] provisions on radioactive waste management. Whereas some differences are expected, as even if there is a considerable amount of international cooperation in the nuclear energy field, and even if international commercial activities of fuel reprocessing and manufacturing

[72] France ratified the Joint Convention the 29th September 1997 and Spain the 30th June 1998.
[73] The Directive had to be transposed before the 22nd August 2013 by Member States.

happen, radioactive waste management is still seen as a national responsibility nowadays[74].

A. Radioactive waste management in France

i. Nuclear industry status

Nuclear power is the largest source of electricity in France, with over 70% of the total electricity production coming from nuclear supplies. If electricity generation from renewable sources is also accounted, that makes about 90% of France's electricity coming from low-carbon sources. Since nuclear power is so important in France, and seeing that France's carbon footprint is relatively smaller compared to other countries that use more fossil fuels, it is undeniable that France presents the nuclear solution, if nothing else, appealing for the international community.

Nuclear energy from civilian reactors in France dates as early as 1962, when the first *Électricité de France* nuclear power plant went into service. The spread of nuclear plants experienced, however, further encouragement in the 1970s. In 1974, the Prime Minister, Pierre Messmer, announced the *Plan Messmer*, which aimed at generating all the electricity in France from nuclear plants only, as at the time, the oil crisis and France's dependence from foreign fossil fuels was hitting the country negatively. This focus on energy independence led to the construction of fifty-six nuclear reactors to satisfy the national needs of electricity over the next fifteen years. It was a salvation for the crisis back then, but a serious problem nowadays, as France is getting ready to shut down most of its reactors in the next few years.

There are currently fifty-seven operational reactors in France, after Unit 1 of the *Fessenheim Nuclear Power Plant* was closed in February 2020. Unit 2 is expected to be closed in June 2020. That makes France the second most important country in the world in number of reactors, only behind the US. At the same time, in the *Flamanville Nuclear Power Plant*, a third reactor has been under construction since 2007, which was expected to replace the equivalent nuclear capacity of the reactors

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[74] SHARRAD, C. A., "Nuclear Fuel Cycles: Interfaces with the Environment", in HARRISON, R. M., *et al.*, *Nuclear Power…, op. cit.,* p. 41.

decommissioned. However, even though the shutdown at the *Fessenheim* plant is taking place, the project in *Flamanville* has been put on hold, after several incidents contributed at tripling the initial budget for the project. For now, the commissioning of the reactor is not expected any earlier than 2022.

The current development of the nuclear energy strategy is framed under the *Loi n° 2015-992, du 17 août 2015, relative à la transition énergétique pour la croissance verte*. It defines the French energy policy and establishes goals to be fulfilled for the transition to a low-carbon economy. It set, for example, a goal of reducing the share of nuclear power in electricity generation to a 50% by 2025, a date that has had to be postponed until 2035 by proposal of the Government to the Parliament. That was because this objective would have been attainable only by using more fossil fuels, which would be against France's international commitments to fight climate change[75]. In any case, in order to meet these goals, the path is drawn in a *Multiannual Energy Plan*[76].

The current energy policy in France still places a huge emphasis on improving the energy independence through research on energy efficiency and domestic generation of energy. That includes renewables but also nuclear power. While an objective is to reduce dependence on foreign fossil fuels, which would reduce the uncertainty regarding its prices' volatility and would also help meeting the commitments described in the Paris Agreement negotiated under the *United Nations Framework Convention on Climate Change* (UNFCCC)[77], the decision on nuclear power is put in a difficult situation.

ii. Radioactive waste management legal framework and institutions

Radioactive waste management in France is framed by three laws. Firstly, the *Loi n° 91-1381, du 30 décembre 1991, relative aux recherches sur la gestion des déchets radioactifs*, also known as *Loi Bataille*. Secondly, the *Loi n° 2006-739, du*

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[75] NEA, *Nuclear Energy Data 2018*, 7416, 2019, p. 82.

[76] MINISTÈRE DE LA TRANSITION ECOLOGIQUE ET SOLIDAIRE, *French Strategy for Energy and Climate. Multi-Annual Energy Plan, 2019-2023, 2024-2028*, 2019.

[77] *United Nations Framework Convention on Climate Change* (UNFCCC) of 9th May 1992, in force from 21st March 1994 and ratified by a total of 197 States.

28 juin 2006, de programme relative à la gestion durable des matières et déchets radioactifs. And thirdly, the *Loi n° 2016-1015, du 25 juillet 2016, précisant les modalités de création d'une installation de stockage réversible en couche géologique profonde des déchets radioactifs de haute et moyenne activité à vie longue*. These are the three main laws involved in drafting the regulation of nuclear waste management in France. Nevertheless, other legal instruments, such as the *Code de l'Environnement*, are mentioned *infra*, as some of the articles contained in those laws have been codified in the Articles L. 541-1 *et seq* and D. 541-1 *et seq*. The *Directive 2011/70/EURATOM* has also changed nuclear regulations in France and its influence will be visible. Furthermore, radioactive waste management activities that require official licenses are subjected to provisions contained in other instruments (*Code du Travail*, *Code de la Santé Publique*, etc.).

After clarifying the legal framework, it is the turn of examining the institutions involved in radioactive waste management in France. Radioactive waste management is a task in charge of the *Agence Nationale pour la Gestion des Déchets Radioactifs* (ANDRA), the National Radioactive Waste Management Agency. Even though ANDRA was initially part of the *Commissariat à l'Énergie Atomique* (CEA), the *Loi Bataille* established ANDRA as an independent public body in charge of the long-term management of radioactive waste, under the administrative supervision of the Ministries of Energy, Research and Environment (Article 13). In 2006, the *Loi du 28 juin 2006* was in charge of completing the 1991 Act, strengthening the missions of ANDRA, as most of the articles from this Act were codified in the *Chapitre II* of the *Titre IV* in the *Livre V* of the *Code de l'Environnement*.

One of the missions recognised in the Article L. 542-12 *Code de l'Environnement* for ANDRA is to update and publish an inventory of the radioactive materials and waste present in France. This is made through the publication of l'*Inventaire national*, in which ANDRA provides every year a complete and exhaustive vision of the quantities of radioactive materials and waste in France. In the last publication made available, some of the interesting numbers regarding the current French stocks of radioactive waste are the following.

Economic sector	Percentage of volume generation
Electronuclear industry	59,6%
Research	27,3%
Defence	9,0%
Non-electronuclear industry	3,4%
Medical	0,7%

Figure 1. Breakdown by economic sector of waste volume (packaged equivalent) already stored or intended to be taken care by ANDRA at the end of 2018[78]

This table contains information on which economic sectors are involved in the generation of radioactive waste in France and for how much volume of waste, in relative numbers, they account for. This reveals the important role of electricity generation through nuclear power in producing over half of the total volume of the French radioactive waste.

Waste type	Waste volume	Radioactivity level
High-level waste	0,2%	94,9%
Intermediate-level long-lived waste	2,9%	4,9%
Low-level long-lived waste	5,9%	0,14%
Intermediate- and low-level short-lived waste	59,6%	0,03%
Very low-level waste	31,3%	0,0001%

Figure 2. Distribution of volumes and levels of radioactivity in waste at the end of 2016[79]

The previous table contains information on the distribution of the radioactive waste generated in France, by type, in terms of volume and the amount of radioactivity they account for, from the 2018 edition of the National Inventory. The table highlights the problem of high-level and intermediate-level long-lived waste, as even if they barely account for a 3% of the total waste volume, they are, by far, the

[78] ANDRA, *Inventaire national des matières et déchets radioactifs 2020*, 2020, p. 15.
[79] *Ibid*.

most dangerous for humans and the environment, accounting for over 99% of the total radioactivity present in the waste.

Finally, if we consider the latest figures in absolute numbers, we find that the waste volume classified by types by the end of 2018 is the following.

Waste type	Declared volume (m^3)	Volume (%)
High-level waste	3.883	0,24
Intermediate-level long-lived waste	42.955	2,61
Low-level long-lived waste	93.663	5,69
Intermediate- and low-level short-lived waste	944.546	57,39
Very low-level waste	557.443	33,87
Short-lived waste	1.982	0,12
Other	1.345	0,08
TOTAL	**1.645.817**	**100,00**

Figure 3. Personal compilation with data from the interactive tool *Localisation des déchets* in the ANDRA website[80]

iii. Final disposal of radioactive waste in France

In France, spent fuel and radioactive waste management comprehends, essentially, all the activities related to the handling, storage (with ulterior retrieval), reprocessing (of spent fuel) and final disposal of that matter, excluding off-site transportation (Art. L. 542-1 *Code de l'Environnement*). ANDRA is in charge of the radioactive waste management and of the final disposal. As we have seen *supra*, different solutions are offered depending on the type of waste considered and the radioactivity content to ensure long-term safety, and France is not an exception.

[80] ANDRA, *Localisation des déchets*, retrieved the 17th April 2020 from https://inventaire.andra.fr/inventaire?field_stocks_year_target_id=52384&region=All&departement=All&exploitant=All&categorie=All&famille=All.

The *Plan national de gestion des matières et des déchets radioactifs* (PNGMDR)[81] is the one in charge of outlining the different disposal solutions for the different types of waste. Drawn up by the *Ministère de la Transition Écologique et Solidaire* and the French Autorité de Sûreté Nucléaire (ASN) for multiyear plans, it is a requirement found in the Article L. 542-1-2 *Code de l'Environnement*. Each PNGMDR draws the balance sheet of the existing management methods, identifies the foreseeable needs of installations for storage and disposal, and specifies the capacity requirements for those.

In general, France has chosen the disposal in repositories as the solution for the long-term management of radioactive waste and ANDRA has adapted each repository site to the type of waste that will be disposed of, to ensure the confinement of the radioactivity found in the waste for as much time as it is needed for that radioactivity to decay.

In particular, the solution offered for very low-level waste and intermediate- and low-level short-lived waste is to store them in superficial repository sites[82]. At present, ANDRA has the following facilities for the disposal of these types of waste:

- *Centre de stockage de la Manche*. It was the first near-surface repository site in France for radioactive waste. It is at the end of the La Hague peninsula, in the commune of *Digulleville*. Exploitation started in the year 1969 and finished in 1994. It was entrusted to ANDRA in 1995. It is currently under a surveillance phase, which started in January 2003, through the publication of the *Décret du 10 janvier 2003 autorisant l'ANDRA à modifier, pour passage en phase de surveillance, le centre de stockage de déchets radioactifs de la Manche*.

[81] MINISTÈRE DE LA TRANSITION ECOLOGIQUE ET SOLIDAIRE, *Plan national de gestion des matières et des déchets radioactifs (PNGMDR) 2016-2018*, 2016.
[82] AUTORITÉ DE SÛRETÉ NUCLÉAIRE, *Déchets radioactifs et démantèlement. Les centres de stockage*, ASN, retrieved the 17th April 2020 from https://www.asn.fr/Professionnels/Installations-nucleaires/Dechets-radioactifs-et-demantelement/Centres-de-stockage.

- *Centre de stockage de l'Aube*. It is a near-surface repository site for low- and intermediate-level short-lived waste, which took over the role from the La Manche site in 1992. It is in the communes of *Soulaines-Dhuys* and *La Ville-aux-Bois*. It offers a storage capacity of 1.000.000 m^3 of waste in total. The confinement is reassured by the geological formation of the rocks in the area. ANDRA was authorised to take care of its exploitation from 1995, with the *Décret du 24 mars 1995 autorisant l'ANDRA à exploiter le centre de stockage de déchets radioactifs de l'Aube*.
- *Centre de stockage de Morvilliers*. It is destined for the very low-level radioactive waste (VLLW), which in France will become more and more important as many nuclear installations are preparing to be dismantled in the next few decades, entailing around one or two million m^3 of VLLW[83]. Operations started in the year 2003 and activities held in the site were extended in 2012. It is located in the commune of *Morvilliers*. Now it also has buildings dedicated to the grouping and storage of waste from small producers from non-electronuclear activities and to the sanitation of contaminated sites. For that reason, this repository, which was initially called CSTFA (*Centre de stockage des déchets de très faible activité*), was renamed as CIRES (*Centre industriel de regroupement, d'entreposage et de stockage*).

These three repository sites are, therefore, aimed for the disposal of the types of waste that are the most voluminous (over 90% of the total waste produced) but the least radioactive. It is for that reason that near-surface disposal is an adequate mean for them. However, the other types of waste that are not suitable for disposal in these sites are the most troublesome, especially in France, where the electronuclear sector is so important.

By the end of the year 2018, France had 3.883 m^3 of high-level waste (HLW) and 42.955 m^3 of intermediate-level long-lived waste (IL-LLW) waiting for a final place

[83] INSTITUT DE RADIOPROTECTION ET DE SÛRETE NUCLÉAIRE, *Radioactive waste management*, 2013, p. 6, retrieved the 18th April 2020 from https://www.irsn.fr/en/publications/thematic/documents/irsn_booklet_radioactive_waste.pdf.

of disposal. It needs to be clarified that, since the reprocessing plant in La Hague is commercial, reprocessing on behalf of, not only French utilities, but foreign too, is carried out there. Therefore, these figures also include the foreign waste that is waiting to be returned to their origin countries (among those, there is Spain). The Article 3 of the 1991 Act outrightly bans the storage of foreign spent fuel and waste within the French borders: "The storage in France of imported radioactive waste, even if their reprocessing has been carried out in the national territory, is prohibited beyond the technical deadlines imposed by reprocessing"[84].

The current strategy of France for the disposal of HLW and IL-LLW is framed under the CIGÉO project, which aims to build a deep geological repository for radioactive waste. Even if in the year 2020, construction has not started yet, the project was envisaged as early as in 1991 with the *Loi Bataille*, which set three research objectives for the HLW management: partitioning and transmutation, long-term storage, but also repositories in deep geological formations.

The 1991 Act was the first act to draw attention to the importance of correctly managing the radioactive waste of high-level and the long-lived types, to ensure the protection of nature, the environment and human health, while taking into consideration the rights of future generations (Article 1). For that reason, it established an obligation for the Government to address the Parliament yearly with a report on the state of research of disposal methods for these types of waste, one of these being deep geological repositories, which would be studied through the construction of underground laboratories. By then, it was the most favoured method of disposal, as most articles in the Act regulated those underground laboratories. The deep geological repositories research was a task of ANDRA (codified in the following years in the Article L. 542-12 *Code de l'Environnement*), also established as an independent agency for the first time with the same Act.

The next step in the development of the CIGÉO project was the *Loi n° 2006-739 du 28 juin 2006*. With this Act, which modified dispositions in the *Code de*

[84] Translated by the author from the original: "*Le stockage en France de déchets radioactifs importés, même si leur retraitement a été effectué sur le territoire national, est interdit au-delà des délais techniques imposés par le retraitement*".

l'Environnement, the preference for deep geological repositories to deal with the safe long-term management of HLW was put into the Law, after fifteen years of research in the field.

It is planned that the CIGÉO will be established in the East of France, on the border between *Meuse* and *Haute-Marne*. The location was chosen after years of research and after finding out that at about 500 metres deep underground, there is a layer of clay rock, which with its permeability properties, would be able to confine the waste safely over long time scales. The centre is intended to be operative for at least a 100 years, but it is designed so that retrieval of the waste is accessible, in order to leave for future generations the possibility of retrieving the waste if safer disposal methods are found. Furthermore, it also recognises the right of future generations to revalorise the waste disposed of[85]. This reversibility concept is, thus, important as with the obligations with respect future generations and the *Loi n° 2016-1015 du 25 juillet 2016* was promulgated in order to modify the *Code de l'Environnement* to include the reversibility character of these repositories (Article L. 542-10-1).

The volume of waste that is expected to be disposed of in the CIGÉO is around 10.000 m^3 of HLW and around 70.000 m^3 of IL-LLW. Therefore, considering the numbers that have been seen before, around 40% and 60% of the capacity for each type of waste respectively is already taken over by the waste produced in the past. For that reason, the DGR concept is important because the repository does not necessarily need to be seen as a solution for the future problems of nuclear energy, but as the remedy of a palpable current problem found in the cooling pools all over the French nuclear sites.

This is the regulatory framework under which the construction of a DGR in France will take place. However, as stated before, it has not yet been built. The *Ministère de la Transition Écologique et Solidaire* has a calendar of the future developments of the project. In the year 2018, ANDRA applied for an authorisation to build the repository, but to be granted, many steps on the way must be reached for the correct

[85] POIROT-DELPECH, S. *et al.*, "Le stockage géologique des déchets nucléaires: une anticapsule temporelle", *Gradhiva*, 28, 2018/2, p. 156-157.

evaluation of the project. It is estimated that the authorisation might be eventually issued around the year 2021 by the Council of State, which would allow for the start of the construction works. Then, by the year 2025, an authorisation by the ASN would be needed to start the pilot phase of the project, which would take at least a decade, to make sure the retrieval of the waste is possible. Finally, if the pilot phase goes well, around the mid-2030s, exploitation of the DGR would be possible[86].

For the low-level long-lived radioactive waste (LL-LLW), which has not yet been mentioned, the disposal method preferred is underground disposal, but not necessarily deep geological disposal. This is a method introduced by the 2006 Act, but has not acquired a project status yet, as research is still ongoing.

B. Radioactive waste management in Spain

i. Nuclear industry status

In Spain, nuclear energy is not the largest source of electricity generation, but one of the largest, next to wind power and combined cycle plants. However, it only accounts for around 21% of the total electricity produced in Spain every year[87]. While France is aiming for the total of electricity generation coming from low-carbon sources, Spain is a country that had to struggle with the coal sector and coal lobbies until recently. With renewable sources, about 60% of Spain's electricity comes from low-carbon sources[88]. In spite of that, the year 2019 marked the end of the coal mining sector. Due to this, carbon emissions in Spain from the electric sector decreased over 30% during 2019. Nevertheless, Spain carbon footprint must be even more reduced – the question is whether the further pursuit of nuclear energy can contribute to this.

[86] MINISTÈRE DE LA TRANSITION ECOLOGIQUE ET SOLIDAIRE, *Démantèlement et gestion des déchets radioactifs*, retrieved the 18th April 2020 from https://www.ecologique-solidaire.gouv.fr/demantelement-et-gestion-des-dechets-radioactifs#e3.

[87] RED ELÉCTRICA DE ESPAÑA, *El sistema eléctrico español. Previsión de cierre 2019*, retrieved the 26th April 2020 from https://www.ree.es/sites/default/files/11_PUBLICACIONES/Documentos/InformesSistemaElectrico/2019/Red-Electrica-Infografia-Sector-ElectricoEspa%C3%B1ol-2019.pdf.

[88] CLUB ESPAÑOL DE LA ENERGÍA, *Balance Energético de 2016 y Perspectivas para 2017*, Biblioteca de la Energía, 2017, p. 86.

Spain has followed quite a different path compared to France in terms of nuclear power through its history. The quest for a nuclear industry started as early as in the year 1964, with the construction of the first Spanish nuclear plant, the *Central Nuclear José Cabrera* and its first reactor. More followed in the 1970s and in the 1980s, although some projects were finally halted in the late 1980s due to the nuclear moratorium set by the *Plan Energético Nacional* in 1983[89]. Since the year 1988, no more nuclear plants have been constructed in Spain. There are currently 7 power reactors in Spain, located in five different locations: *Almaraz* (*Cáceres*), *Trillo* (*Guadalajara*), *Cofrentes* (*Valencia*), *Ascó* and *Vandellós* (*Tarragona*), which are considered to have an overall good performance[90].

ii. Radioactive waste management legal framework and institutions

Parallelly to the development of nuclear plants, an institutional framework was also developing behind. Nuclear energy research started with the creation of the *Junta de Energía Nuclear* (JEN) the year 1951 by the *Decreto-ley de 22 de octubre de 1951 por el que se crea la Junta de Energía Nuclear*. This body was created to "guide and direct the research, studies, experiences and operations leading to the best application of nuclear energy for national purposes" (Article 2)[91]. Among these was to pay attention to the "specialized training of scientists and technicians in problems directly related to nuclear energy"[92] (Article 2, letter e). However, to our interest, nuclear waste was not mentioned as a problem itself, as it was too early in the nuclear energy days.

As the nuclear industry became increasingly complex, so did the framework. On one side, the *Ley 25/1964, de 29 de abril, sobre energía nuclear* was approved. As the world started to see the power of nuclear energy in terms of peaceful

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[89] *Plan Energético Nacional 1983*, *Boletín Oficial de las Cortes Generales*, 42, 14th May 1983, p. 435.

[90] NEA, *Nuclear Energy Data 2018*, *op. cit*., p. 60.

[91] Translated by the author from the original: "*[O]rientar y dirigir las investigaciones, estudios, experiencias y explotaciones conducentes a la mejor aplicación de la energía nuclear a los fines nacionales*".

[92] Translated by the author from the original: "*[F]ormación especializada de científicos y técnicos en los problemas directamente relacionados con la energía nuclear*".

applications, Spain was hoping that nuclear power could experience an increasingly important role in the energy supply scheme. It aimed at establishing a legal framework that ensured that the development of nuclear energy respected the protection of humans, things, and the environment from ionising radiations.

In the 1964 Act, radioactive waste is mentioned for the first time. In fact, it established a difference between "*desechos radiactivos*" and "*residuos radiactivos*". The first ones are radioactive materials that are formed during the production process or use of nuclear fuels or whose radioactivity has been caused by exposure to the radiation inherent in such process, while the second are any kind of radionuclide-contaminated waste for which no use is intended. The relevant concept in terms of disposal is the second, but it must be underlined that in the original 1964 version, only its Article 38 contained a disposition on nuclear waste, stating that "nuclear and radioactive facilities that work with radioactive substances are obliged to have special facilities for the storage, transport and handling of radioactive waste"[93]. Nevertheless, none of those actions included the final disposal of the waste, indicating it was not a problem in the beginning. The 1964 Act is still enforceable in Spain yet has suffered many changes throughout its over fifty years of history.

Despite that, to make further reference to the legislative evolution, the development of the institutional framework needs to be addressed. Moreover, the tasks that the JEN had to take care of, which the 1951 Act referred to, progressively broadened. It required the creation of new bodies, more specialised in certain aspects of nuclear power, to which powers previously attributed to JEN were delegated.

Firstly, in 1972 the State-owned company *Empresa Nacional del Uranio, S.A.* (ENUSA) was created, to deal with the front-end activities from the nuclear fuel cycle. That is, the management of uranium provisions or mining activities -back

[93] Translated by the author from the original: "*Las instalaciones nucleares y radiactivas que trabajen con sustancias radiactivas quedan obligadas a contar con instalaciones especiales para almacenamiento, transporte y manipulación de residuos radiactivos*".

then, the existing uranium deposits in Salamanca-, and the process of conversion and enrichment to supply all the Spanish nuclear plants.

Secondly, the *Ley 15/1980, de 22 de abril, de creación del Consejo de Seguridad Nuclear* separated some of the functions from the JEN and transferred them to the newly established *Consejo de Seguridad Nuclear* (CSN), as the sole organism competent in nuclear safety and radiological protection matters (Article 1). The remaining functions were delegated to the *Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas* (CIEMAT), which still continues doing research and development (R+D) activities on nuclear fission, but widened its research fields to the investigation of alternative energy technologies and the study of the environmental energy impact after the enactment of the already repealed *Ley 13/1986, de 14 de abril, de Fomento y Coordinación General de la Investigación Científica y Técnica*.

Finally, the creation of the *Empresa Nacional de Residuos Radiactivos, S.A.* (ENRESA) caused the final disappearance of the JEN through the promulgation of the *Real Decreto 1522/1984, de 4 de julio, por el que se autoriza la constitución de la Empresa Nacional de Residuos Radiactivos, S.A.*

Until then, radioactive waste management was regulated through the *Real Decreto 2967/1979, de 7 de diciembre, sobre ordenación de actividades en el Ciclo del Combustible Nuclear*. It established that ENUSA was to be responsible, among many other tasks, of the management of irradiated use fuels (Article 3.1) and JEN, of the activities referred to the final stockage of radioactive waste (Article 3.2). Nevertheless, this Royal Decree did not consider other aspects of the radioactive waste management cycle, such as the stockage of radioactive waste not produced within the fuel cycle or the dismantlement of nuclear sites. Furthermore, the financial aspects, for instance, the backing of these management activities by the generators of the waste (by application of the "polluter pays" principle) would be better managed by a new organism specialised in these matters for correct cost evaluation. These factors fostered the creation of ENRESA in 1984.

The 1984 Royal Decree stated in its Article 2 some of the tasks delegated to ENRESA, such as: "Search sites, conceive, build and operate the centres for the temporary and permanent storage of high, low and intermediate radioactive waste"[94] (letter b), "Manage operations derived from the closure of nuclear and radioactive facilities"[95] (letter c), or "Carry out the necessary technical and economic-financial studies that take into account the deferred costs derived from the management of radioactive waste, in order to establish the appropriate economic policy"[96] (letter h). That is, a detailed relation of the briefly stated tasks in the Article 38 of the 1964 Act.

This Decree was abrogated by *Real Decreto 1349/2003, de 31 de octubre, sobre ordenación de las actividades de la Empresa Nacional de Residuos Radiactivos, S. A. (ENRESA), y su financiación*, with the aim to reunite all the relevant regulations referred to ENRESA that were scattered throughout diverse decrees and ministerial orders. However, this one was also repealed by the *Real Decreto 102/2014, de 21 de febrero, para la gestión responsable y segura del combustible nuclear gastado y los residuos radiactivos.*

This was done due to the need to include modifications in some dispositions by the transposition of the already mentioned Directive 2011/70/EURATOM. Although most of the requirements and the basic principles applicable to radioactive waste management contained in the EU/EURATOM instrument were already part of the national legal framework, it was considered necessary to elaborate a new decree to take into account the dispositions that were not yet included, but also include further development in the articles in the 1964 Act regarding the management of spent nuclear fuel and radioactive waste.

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[94] Translated by the author from the original: "*Buscar emplazamientos, concebir, construir y operar los centros para el almacenamiento temporal y definitivo de los residuos de alta, baja y media radiactividad*".

[95] Translated by the author from the original: "*Gestionar las operaciones derivadas de la clausura de las instalaciones nucleares y radiactivas*".

[96] Translated by the author from the original: "*Efectuar los estudios técnicos y económico-financieros necesarios que tengan en cuenta los costos diferidos derivados de la gestión de los residuos radiactivos, al objeto de establecer la política económica adecuada*".

The 2014 Royal Decree aims to summarise "the regulation for the responsible and safe management of spent nuclear fuel and radioactive waste when they come from civilian activities, in all its stages, from generation to final storage, in order to avoid imposing undue burdens on future generations, as well as the regulation of some aspects related to the financing of these activities" (Article 1.1) [97].

In that sense, as we mentioned *supra*, the 1964 Act has suffered many changes through its history, but one of the most relevant is the inclusion of the Article 38 *bis* by the *Ley 11/2009, de 26 de octubre, por la que se regulan las Sociedades Anónimas Cotizadas de Inversión en el Mercado Inmobiliario* through its 9th Final Disposition.

This article establishes different principles that must inform the legal framework regarding radioactive waste management. Firstly, it states that radioactive waste management at large is an essential public service that is reserved to the State via the Article 128.2 of the Spanish Constitution. In those terms, the task is officially delegated to the State-owned ENRESA, which will carry out its duties respecting the "*Plan General de Residuos Radiactivos*" (PGRR) approved by the Government. Secondly, that ENRESA is overseen by the *Ministerio de Industria, Turismo y Comercio*, through its *Secretaría de Estado de Energía*, which will also exercise its faculties of expropriation when they are needed for the fulfilment of its purposes. And thirdly, it states the ownership of the radioactive waste by the State once it has been finally stored. Likewise, the State will be responsible of its vigilance for as long as it is needed.

This would be the current framework of radioactive waste management in a broader sense: the consolidated version of the 1964 Act, the 2014 Royal Decree and the General Plans approved by the Government. Moreover, it is a duty that corresponds to ENRESA, the Spanish counterpart of the French ANDRA.

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[97] Translated by the author from the original: "*[L]a regulación de la gestión responsable y segura del combustible nuclear gastado y de los residuos radiactivos cuando procedan de actividades civiles, en todas sus etapas, desde la generación hasta el almacenamiento definitivo, con el fin de evitar imponer a las futuras generaciones cargas indebidas, así como la regulación de algunos aspectos relativos a la financiación de estas actividades*".

To study the size of the radioactive waste problem in Spain, the latest data available is found in the 2020 First Draft of the 7th PNRR, which not only includes the current inventory of radioactive waste by types, but also includes a provision of the total waste generated by the dismantlement of shutdown nuclear reactors, as well as the generated, by the remaining operating plants until its dismantlement. It needs to be put in relation with another plan submitted by the Government in 2019, the *Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030*.

Under the *Paris Climate Agreement*, it is the EU that responds to the requirements set down by it for the countries. Therefore, the EU is in charge of elaborating the framework for the energetic and climatic policies in the Member States. In that direction, the EU has established certain goals under the *Clean energy for all Europeans* strategy to make sure the Member States help deliver the EU's Paris Agreement commitments for reducing greenhouse gas emissions. Among the transposition of new legislative proposals, the EU asks each Member State to submit their National energy and climate plan (NECPs), so that the European Commission can oversee to which extent the joint compliance is achieved and establish actions to correct possible deviations. Under this legal mandate, Spain elaborated this PNIEC, submitted the 20th January 2020.

This PNIEC confirms that ENRESA has reached an agreement with the owner companies of the Spanish nuclear park to establish a calendar for the orderly and phased closure of the seven remaining operative nuclear reactors[98]: four of them will be shut down during the validity of that plan, that is, before the year 2030, and the other three will be likewise shut down before 2035[99].

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[98] MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *ENRESA presenta en la Secretaría de Estado de Energía el borrador del 7º Plan General de Residuos Radiactivos*, Press Release, 16th March 2019, retrieved the 26th April 2020 from http://www.enresa.es/esp/inicio/conozca-enresa/publicaciones/category/8-notas-de-prensa?download=113:enresa-presenta-en-la-secretaria-de-estado-de-energia-el-borrador-del-7-plan-general-de-residuos-radiactivos.

[99] MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030*, 2019, p. 277.

This scenario is therefore considered in the Draft of the 7th PNRR, to include a complete relation of the current and the expected final stock of radioactive waste after all the nuclear plants will be closed. In that sense, the Draft distinguishes between four kinds of waste to establish these scenarios: very low-level waste (RBBA), low- and intermediate-level waste (RBMA), especial waste (RE) and high-level waste (RAA), mainly spent nuclear fuel. Thus, this is the magnitude of the problem for Spain:

Waste type	**Approximated volume (m^3)**			**%**
	Inventory by 31/12/18	**Prevision**	**Total inventory**	
RBBA	22.500	101.000	123.500	52
RBMA	40.300	56.200	96.500	41
RE	200	5.900	6.100	3
RAA	7.300	3.100	10.400	4
TOTAL	**70.300**	**166.200**	**236.500**	**100**

Figure 4. Spanish National Inventory[100]

It is significant the difference between the Spanish and the previously seen French inventory of nuclear waste, as it seems Spain has a bigger issue with high-level waste, surprisingly, when in fact Spain has quite a lot less nuclear reactors generating it. However, Spain classifies waste more broadly than France (three *versus* five categories), and it is very likely that the HLW category in Spain includes waste that in France is considered as low- and intermediate-level long-lived waste. We will try to draw conclusions from it *infra*.

100 MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *Borrador de 7º Plan General de Residuos Radiactivos*, 2020, p. 29.

iii. Final disposal of radioactive waste in Spain

Carrying on with the legal framework, our main interest is to see how the final disposal of that waste will be carried out in Spain, which is mentioned in the 2014 Decree. There are two main references to final disposal of nuclear waste in it.

Firstly, the Article 13, which regulates the final disposal of radioactive waste abroad. In principle, radioactive waste generated in Spain must be disposed of within its borders, but there are cases in which disposal abroad is possible when certain requirements established by the *Directive 2011/70/EURATOM* are met. Nevertheless, the waste must be directed to the disposal at a final disposal site, and as we have seen *supra*, no country has yet succeeded to build one of these facilities.

And secondly, radioactive waste disposal is mentioned as in the sense that the plans and technical solutions for the management of spent nuclear fuel and radioactive waste, from generation to final storage, must be included as part of the PGRR (Article 6, letter d).

The PGRR, as seen *supra*, is elaborated by the Government, by proposal of the *Ministerio de Industria, Energía y Turismo*, after a report of the CSN is examined. It lays out "the strategies, necessary actions and technical solutions to be developed in Spain in the short, medium and long term, aimed at the responsible and safe management of spent nuclear fuel and radioactive waste, the dismantling and decommissioning of nuclear facilities and other related activities" (Article 5.2) [101]. The plan must be reviewed periodically, considering the scientific and technical progress that has been made, as well as the own experiences and recommendations derived from peer-reviewed processes with counterparts abroad (Article 5.3).

[101] Translated by the author from the original: "*[L]as estrategias, actuaciones necesarias y soluciones técnicas a desarrollar en España en el corto, medio y largo plazo, encaminadas a la gestión responsable y segura del combustible nuclear gastado y los residuos radiactivos, al desmantelamiento y clausura de instalaciones nucleares y al resto de actividades relacionadas con las anteriores*".

These are the legal prescriptions. What we see in reality is that the current PGRR in force is a plan from 2006[102], and only by date of 16th March 2020, the First Draft of the 7th PGRR was submitted by ENRESA to the *Ministerio para la Transición Ecológica y el Reto Demográfico*. Since 2006, the *Directive 2011/70/EURATOM* was introduced and regulated the content of the national plans in its Article 12. Therefore, the 6th PGRR currently in force does not comply with the requirements laid down in the EU/EURATOM legislation.

In terms of disposal, as it has been briefly mentioned *supra*, it distinguishes between very low-level waste (RBBA), low- and intermediate-level waste (RBMA), and high-level waste (RAA), a part from the denominated especial waste (RE), which is made up of certain components part of the reactor and is treated as RAA. Both PGRR, the 2006 in force and the 2020 Draft, classify these types of wastes in two groups: those that can be finally disposed of in the Storage Site of *El Cabril* (RBBA and RBMA) and those that cannot due of their high activity (RAA and RE).

The *El Cabril* radioactive waste disposal facility is the only final disposal site Spain for waste of types RBMA and RBBA, which is most of the waste generated by hospitals, research centres, industries, and most importantly, nuclear plants in Spain. It has been operative since October 1992. It was initially destined only for RBMA, but it has been storing RBBA since the year 2008. By the 31st December 2019, there were around 34.471 m^3 of RBMA and 17.383 m^3 of RBBA stored.

This data, combined with the provisions made in the 7th PGRR Draft, suggest there will be needed new facilities in the upcoming years, especially for RBMA, as it is already taking up around 79% of the current site capacity. But regardless of a new built in the future of a disposal facility, the *El Cabril* facility will need to be overseen for, at least, three hundred years following its closure, the time needed for the radioactivity levels in the RBMA to decay to its natural levels.

This is the current solution in Spain for these types of waste, which are the ones that take up the most volume of the waste generated each year, but the ones that do

[102] MINISTERIO DE INDUSTRIA, TURISMO Y COMERCIO*, Sexto Plan General de Residuos Radiactivos (6º PGRR)*, 2006.

not require bigger efforts due to the lower levels of radioactivity present in them. A totally different scenario awaits the high-level waste generated daily all over Spain.

The 2006 PGRR envisaged the creation of a *Centralised Temporary Storage* (CTS) facility for the high-level waste and spent fuel, awaiting the construction of a final DGR. As seen *supra*, though, no country has any DGR operative at the moment, as there is a long and complicated process behind. However, Spain needs this CTS type of facility to accommodate all its RAA and RE in a single location, as it gets ready for the dismantlement of all the nuclear power plants, reaching the end of their operational lives in the next few years.

The CTS would also enable the return for storage of the RAA originated from the *Vandellós I Nuclear Power Plant*, which was temporarily stored in France. In the 2006 PGRR it was stated: "[…] The contractual commitments contemplate that they must return to Spain between 2010 and 2015, and there are strong economic penalties if the first transport, which must be highly active vitrified waste, does not take place before December 31, 2010"[103]. Unexpectedly, the CTS facility has not yet been built and ENRESA has had to face a daily penalty of around 75.000€ since July 2017 and will continue to until the CTS is built and the waste is finally retrieved, although the money will be returned once the waste is retrieved, subtracting maintenance expenses[104].

In the 6th PGRR, it predicted that this CTS would be available by 2010, as the construction of a CTS was the main strategy in terms of RAA type of radioactive waste management in Spain. In 2009, through the *Resolución de 23 de diciembre de 2009, de la Secretaría de Estado de Energía, por la que se efectúa la convocatoria pública para la selección de los municipios candidatos a albergar el emplazamiento del Almacén Temporal Centralizado de combustible nuclear gastado y residuos radiactivos de alta actividad y su centro tecnológico asociado*,

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[103] MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *Borrador de 7º Plan General de Residuos Radiactivos*, *op. cit.*, p. 40; translated by the author from the original: "*[…] los compromisos contractuales contemplan que deben volver a España entre los años 2010 y 2015, existiendo fuertes penalizaciones económicas si el primer transporte, que deberá ser de residuos vitrificados de alta actividad, no tiene lugar antes del 31 de diciembre de 2010*".
[104] ENRESA, *Informe Anual 2018*, 2019, p. 72-73.

a public tendering for the quest of the town in which the CTS would be built was launched.

After the selection process, with the publication in the *Boletín Oficial del Estado* (BOE) of the *Resolución de 18 de enero de 2012, de la Secretaría de Estado de Energía, por la que se publica el Acuerdo de Consejo de Ministros de 30 de diciembre de 2011, por el que se aprueba la designación del emplazamiento del Almacén Temporal Centralizado de combustible nuclear gastado y residuos de alta actividad y su Centro Tecnológico Asociado*, the town of *Villar de Cañas* (*Cuenca*) was chosen, but not without controversy.

While the decision of *Villar de Cañas* to run for the public tendering was consensual with its citizens based on the need of economic reactivation of the town, the opposition from nearby areas arose, including the Autonomic Government. This one, the *Junta de Castilla-La Mancha,* tried to boycott the project through a legal instrument: the *Acuerdo de 28/07/2015, del Consejo de Gobierno, por el que se inicia el procedimiento para la ampliación del Espacio Protegido Red Natura 2000 Laguna del Hito (ES0000161) y de la modificación del Plan de Ordenación de los Recursos Naturales de la Reserva Natural de la Laguna Hito*, under the legal shelter of the *Directive 2009/147/EC, of 30 November 2009, on the conservation of wild birds*.

With it, the Autonomic Government, tried to block the construction of the CTS through the extension of an area protected by the Natura 2000 network. Not being protected by it was one of the requirements for the election of the final site and its extension would have put *Villar de Cañas* under its area of influence, therefore making it ineligible to hold the CTS. This decision was appealed by the Central Government through the State's attorney, and while the *Tribunal Superior de Justicia de Castilla-La Mancha* issued a precautionary measure on the suspension of the construction of the CTS, the Spanish supreme court, the *Tribunal Supremo* considered otherwise.

As stated by the *Tribunal Supremo*[105], "if we carry out a correct judgment of balance between the competing interests, it seems to us prevalent to preserve the adequate management of radioactive waste in order to achieve better nuclear safety, while the lawsuit is being substantiated, than the immediate approval of the expansion of a protected space for birds and the modification of a Natural Resources Management Plan"[106].

While that was only a declaration on the precautionary measures, it states the importance under the view of the *Tribunal Supremo* on the need of finding a solution for nuclear waste.

However, the final solution was given by the TSJ 206/2018 the 30th July 2018, which declared the autonomic regulations were invalid, acknowledging that the Autonomic Government could not "pursue a surreptitious purpose of obstructing the exercise of state competence, taking refuge in the appearance of the need for expansion and conservation of natural spaces, however commendable such a purpose may be"[107].

In any case, the solution arrived a bit late, as by the 18th July 2018, it surfaced the news that the *Ministerio para la Transición Ecológica* had decided to paralyse the construction permit for the CTS, which contributed to the general delay that had been observed in terms of radioactive waste management in Spain. It was justified on the grounds of the need of a new PGRR, which in turn had to be based on the

"[105] TRIBUNAL SUPREMO (Sala de lo Contencioso, Sección 5ª), judgement 5769/2016, of 16th December (Rec. 672/2016).

[106] Translated by the author from the original: "*Si efectuamos un correcto juicio de ponderación entre los intereses enfrentados, nos parece prevalente preservar la adecuada gestión de los residuos radioactivos en orden a una mejor seguridad nuclear, mientras se sustancia el pleito, que la aprobación inmediata de la ampliación de un espacio protegido para las aves y la modificación de un Plan de Ordenación de los Recursos Naturales*".

[107] TRIBUNAL SUPERIOR DE JUSTICIA DE CASTILLA-LA MANCHA (Sala de lo Contencioso-administrativo, Sección 1ª), judgement 209/2018, of 30th July (Rec. 412/2015); translated by the author from the original: "*Perseguir una finalidad subrepticia de obstrucción del ejercicio de la competencia estatal, amparándose en la apariencia de la necesidad de ampliación y conservación de espacios naturales, por muy loable que pueda resultar tal propósito*".

new PIEMEC, to issue a final decision on the construction of the CTS in *Villar de Cañas*, even though millions of euros had already been invested in the site.

The First Draft of the 7th PGRR considers the launch of a CTS for RAA and RE types of waste by the year 2028, and counts with the availability of a Waiting Containers Warehouse, as part of the CTS facility, by 2026[108], allowing for the retrieval of the first containers from France. In that direction, this would allow the storage of the waste for around sixty years, as the availability of a deep geological repository is not expected any earlier than the year 2073[109].

In terms of radioactive waste management, this framework leaves Spain with a satisfactory disposal solution for around 95% of the waste it generates, but uncertainty around how it will deal in the future with the final disposal of the most radioactive types of waste, the high-level and the spent nuclear fuel, for which no proposed solution is sufficiently mature yet. The water pools in the Spanish nuclear power plants are temporarily storing this waste waiting for its cooling, but will not be for long, as the nuclear dismantlement will require for these pools to be emptied, while there is nowhere to put this waste. The developments in next few decades will be crucial for the fate of the waste in Spain, but so will for the rest of the world.

[108] MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *Borrador de 7º Plan General de Residuos Radiactivos*, *op. cit*., p. 13.
[109] MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO, *Borrador de 7º Plan General de Residuos Radiactivos*, *op. cit*., p. 53.

V. Conclusions

First. Performing a research on nuclear energy and radioactive waste has proved to be challenging beyond the actual difficulties to understand concepts from fields that one is not used to, namely chemistry or geology. It is, in fact, for the lack of impartial sources of information, as nuclear energy is such a polarised topic, and a lot of reading has to be done to be able to distinguish the biased from the non-biased sources of information. Nuclear energy is a difficult subject to have an own opinion in any case.

Second. The risk of ionising radiations must be put in perspective to fully assess it. The damages that a nuclear accident could cause in terms of radiation emissions are fatal for human life and that cannot be discussed, as experiences such as Chernobyl have taught us. But while renewable sources of energy are still quite underdeveloped, the direct alternatives to nuclear power are fossil-fuelled plants, which contribute to air pollution. That is not a meaningless concept. The World Health Organisation (WHO) counts the deaths due to air pollution in millions, a disaster that is as disturbing as the possibility of a radiation emission from a nuclear power plant in your home country.

Third. If one could guarantee the safety and correct functioning of nuclear plants, these could be put at great use in developing countries: they are relatively cheap in terms of electricity generation, powerful and could help the further development of local industries. Not only in economic terms, but on national public health terms, as those are the countries in which the incidence of deaths by air pollution is the highest, according to WHO data[110]. However, renewable energies would still be preferred, as unless there is international collaboration in terms of nuclear waste management, it is hard to imagine when solutions for radioactive waste could be achieved in those countries, if they opted for nuclear power.

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[110] GLOBAL HEALTH OBSERVATORY (GHO) DATA, *Mortality and burden of disease from ambient air pollution*, World Health Organisation, retrieved the 2nd May 2020 from https://www.who.int/gho/phe/outdoor_air_pollution/burden/en/.

Fourth. Opposition to nuclear power is commonly grounded in terms of the safety of plants and radioactive waste. Nevertheless, the list of challenges it faces to become a reliable source of energy goes beyond those two. For example, the lack of professionals in nuclear fields, or at least, not enough to face an increment in the number of reactors in the next few decades. Besides, uranium availability could be solved through fuel reprocessing, but this would "democratise" the obtention of plutonium. Managing proliferation risks would require international surveillance to make sure countries are not developing weapons' programmes. Furthermore, optimal safety measures of nuclear plants could not exclude the possibility of them being targets of terrorist attacks. The most realistic drawback, in any case, it's the economic: they are expensive to build, have increasing costs over time, and unless we decide to increase the life-time of current reactors, building new ones do not make economic sense.

Fifth. Radioactive waste management deals with the many stages the waste goes through after it is irradiated, and it is considered there is no further use for it. The act of disposal is the most complex, as it needs to be reassured this will not put in danger humans and the environment. However, even if it can come in many shapes and forms, we can be relieved that in nuclear countries, most of that generated waste enjoys of a legal, technological and institutional framework that offers a satisfactory solution for its long-term disposal. As seen, France has two disposal facilities and Spain one, which deal with around 90% of the waste generated yearly.

Sixth. There is scientific international consensus on DGR being the ideal solution to get rid of HLW, but the legal frameworks in which the development and construction of DGR should take place are either non-existent or alarmingly delayed. The consensus needs to be put in contrast with the general principle informing radioactive waste legal instruments saying each country is responsible for dealing with the own waste. There are currently zero DGR operative in the world, but nuclear power plants operating in around thirty countries worldwide. This bottleneck problem might not seem urgent now, but it will in less than twenty years, as countries prepare to unplug most of the reactors built in the 1970s and 1980s.

Seventh. The relevance of the *Joint Convention* comes from being the first binding legal instrument in the field of radioactive waste management. Nevertheless, Contracting Parties still have a margin of freedom when determining many aspects related to it, including the boundaries between categories of waste. This creates difficulties, as data in the national inventories is not comparable, as it happened with France and Spain. Beyond the comparison and despite the different industry statuses which entail different levels of complexity in terms of radioactive waste management, let it be clear that both countries are in need of a long-term disposal method for the high-level waste, which they do not have yet.

Eight. After studying the issue of radioactive waste and the lack of satisfactory and operational methods for high-level waste even in the most advanced countries, it makes us think that while the nuclear plants in operation are helping with the climate change fight, it would not make sense to opt for nuclear as a replacement for fossil fuels in the short term, or not until there are DGR in operation and prove to be a safe way to dispose of radioactive waste. This will still take many years, and even then, renewable energy sources might prove to be more competitive than nuclear power. Therefore, we cannot make a final statement on the adequacy of nuclear power in the future, but we can agree that many factors need to change for this to happen: economic, social, legal, etc.

Ninth. The intention of total denuclearisation in the following years by France and Spain has been brought to light, through their decisions on nuclear moratoriums, with important consequences. In Spain in 1982, this change in the energetic national policy was partly the result of a change in the Government, which hints a big issue with, not only radioactive waste management, but nuclear energy policies in general: its politization. However, while it is probably impossible to separate the stance on nuclear power and the own ideology, it is time to open up an interdisciplinary debate on nuclear power to find the best solution for radioactive waste and reach a common agreement between society members, to avoid the "back-and-forth" effect change in governments produce in determining the role of nuclear power as a part of the country's energy mix and the regulations related to it.

Tenth. If we had to summarise the issue of radioactive waste in a word, it would be *delay*. While the Preamble of the *Directive 2011/70/EURATOM* acknowledges that “[s]ome Member States consider that the sharing of facilities for spent fuel and radioactive waste management, including disposal facilities, is a potentially beneficial, safe and cost-effective option when based on an agreement between the Member States concerned”, this cannot justify any more delays in the development of long-term disposal strategies for radioactive waste at a National level. The experience, namely the *Villar de Cañas* CTS, has shown that any attempt to establish a disposal site will be treated as an attempt to build a “nuclear cemetery”. That was for a temporary disposal facility and to store the waste generated in Spain. How can we expect any country to decide to build a deep geological repository for the waste of other countries without any kind of local opposition?

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