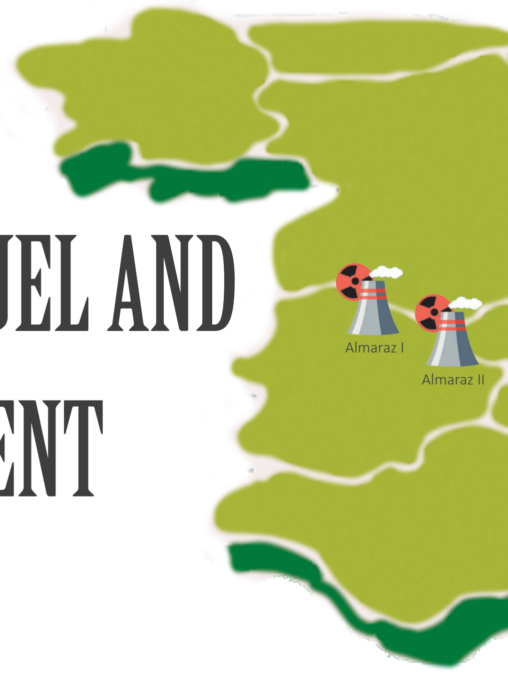


NUCLEAR ENERGY AND SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT

AT present, there are the following 7 active nuclear plants in Spain for the production of electrical energy: Almaraz I and II (Cáceres), Ascó I and II (Tarragona), Vandellós II (Tarragona), Cofrentes (Valencia), and Trillo (Guadalajara), which according to REE source, in last year 2019, with a total installed power of this technology that currently represents 6.8% of the total (Ttl. in Spain 104,801MW), have produced 55,824 GWh, 22.6% of the total electricity, ranking second among the different technologies, after renewables (not including hydroelectric), whose installed powers already reached 36%, producing 29% of the respective totals. They have also constituted a so-called clean energy source, with 36% among those energies with the lowest polluting emissions to the environment. There are 3 other plants already shut down and in different phases of dismantling: Santa María de Garoña (Burgos), José Cabrera (Guadalajara) and Vandellós I (Tarragona).

The 7 power plants currently active are of the (LWR) type, cooled by light water and in turn are divided into the types (PWR) pressurized water reactors and (BWR) boiling water reactors. All of them use as fuel for nuclear fission uranium rods enriched at 3-4% in the fissile isotope U235, manufactured from natural uranium which in nature is found with percentages of 99.3% of U238 and only 0, 7% of U235. The fuel rods, made up of UO2 enriched uranium dioxide ceramic pellets, produced in a sintering process, are introduced into corrosion-resistant metal fuel cladding, hermetically sealed and loaded into the reactor in fuel elements made up of a large number of bars at precise distances. In this state, before their use in the reactor, these low radiation elements are easily manipulated and transportable. The ENUSA facility in Juzbado (Salamanca) manufactures this type of fuel element for power plants.

The operation of these plants is based on the use of the high heat energy produced by nuclear fission reactions, to obtain water steam that can be transformed into electricity by means of a turbine-generator set.

In this type of light water reactors, water has a double function, as a moderator, reducing the speed of the emitted neutrons, which are absorbed by the heavy atoms of U235, maintaining the fission reaction, and as a coplant that transmits heat through a heat exchanger, or directly to the turbine, depending on the PWR / BWR type.

Installed power capacity in Spain as at 31 december 2019 %

Nuclear	6,8%
Coal	8,8%
Combined cycle	23,4%
Cogeneration	5,5%
Non-renewable waste	0,4%
Pumped-storage	3,2%
Wind	24,1%
Hydro	16,3%
Solar photovoltaic	8,2%
Solar thermal	2,2%
Others renewables	1,0%
Renewable waste	0,1%

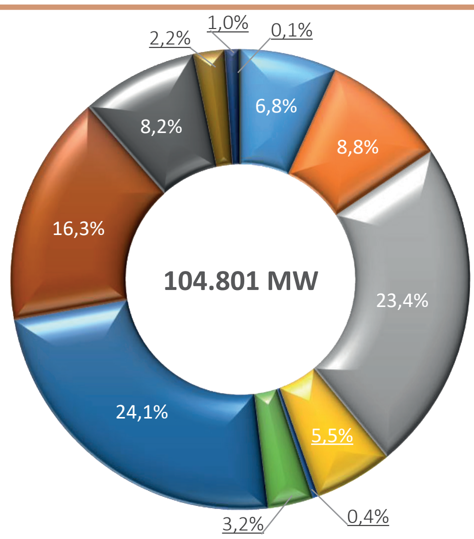


Fig.1 Electric power installed in Spain

Fig.2 Diagram of PWR nuclear plant

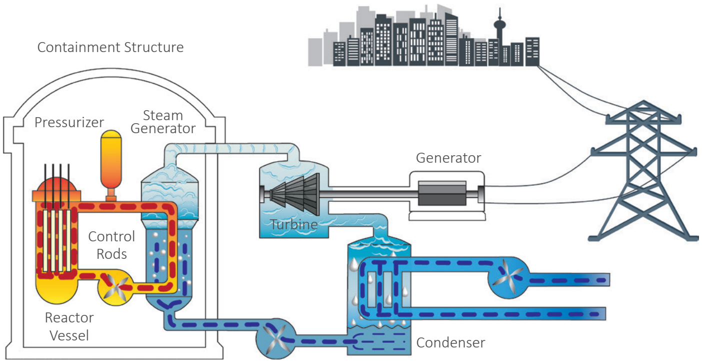
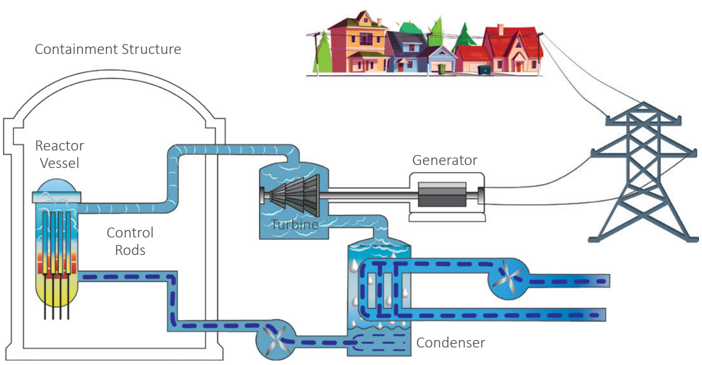


Fig.3 Diagram of BWR nuclear plant



CLASSIFICATION OF RADIOACTIVE WASTE

- Very Low Level Waste(VLLW)

Stored in C.A, El Cabril facility , or in waste´s producer facility

- Low and Intermediate Level Waste, short-life (LILW):

Those whose activity is due to the presence of beta or gamma emitting radionuclides with a short or medium half-life (less than 30 years), and whose content in those with a long life is very low and limited.

- Special waste(SW)

Nuclear fuel attachments, generally metallic components, coming from the vessel and inside the reactor, and others not susceptible due to their high rate of radiation by neutron activation , to be managed in the permanent storage facility available today in Spain, in El Cabril (Córdoba), for very low, low and medium level waste.

- High level waste (HLW)

Those containing significant concentrations of long-life alpha emitters and beta-gamma emitters , that generate significant heat. Among them is spent fuel (SF), which once unloaded from the reactors will not be reprocessed, as well as the waste, already vitrified, produced in the past in reprocessing.

The reactor also has numerous control elements that limit the neutron population and reaction stability, and multiple safety and shield elements that prevent the release of radioactivity to the outside.

The main challenge that this type of energy presents, worldwide, is the safe treatment of all spent fuel (after about 3 years of production in the reactor), and of other radioactive waste produced within the reactor, as well as that of radioactive elements in decommissioning at the end of the useful life of the nuclear power plants, so that they do not pose any risk.

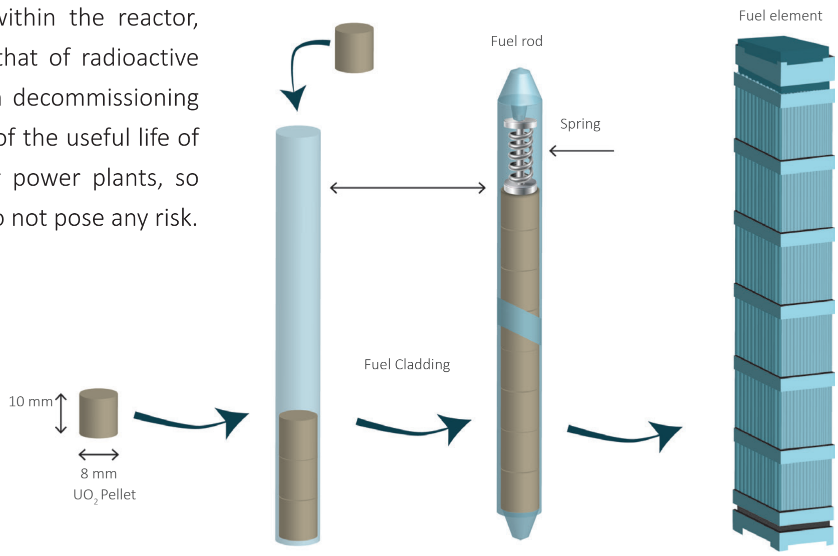


Fig.3 Fuel element

Figures of table 1 impliy that, as of the inventory date, 30% of the total expected radioactive waste has already been generated.

Over its service life, the European fleet of nuclear reactors (excluding Russia and Slovaquia), is estimated to produce around 6.6 million m³ of nuclear waste . The calculation includes waste from the operation, spent nuclear fuel and reactor decommissioning. With a 30 percent share, France would be Europe's largest producer of nuclear waste, followed by the UK (20 percent), Ukraine (18 percent) and Germany (8 percent). These four countries account for more than 75 percent of Europe's nuclear waste.

Low, medium and high radioactive waste are treated and stored in different ways.

After the end of its production cycle in the reactor, the spent fuel of high radioactivity and still producing high heat is temporarily stored in a pool of water located inside the plant, built of concrete with stainless steel walls, thus creating a radiation barrier and allowing its cooling.

Subsequently, there are the following treatment alternatives (Fig. 5):

Total inventory by type of waste as of December 31, 2018

Type of waste	Estimated Volume (m^3)				
	Inventory at 2018/12/31	Expected generation		Total inventory	
		Maximum	Minimum	Maximun	Minimum
VLLW	22.500	117.900	84.000	140.400	106.500
LILW	40.300	61.400	50.900	101.700	91.200
SW	200	5.900	5.800	6.100	6.000
SF AND HLW	7.300	3.300	2.800	10.600	10.100
TOTAL	70.300	188.500	143.500	258.800	213.800

Table 1- National Inventory, published by ENRESA on July 14th, 2020

OPEN CYCLE: After an indefinite period of stay in the pool RACKs, or if there is a saturation of the pool capacity in a subsequent dry storage in an ITS (individualized temporary storage), the spent fuel is conditioned for definitive storage as residue.

CLOSED CYCLE: After its temporary storage, the spent fuel is reprocessed by separating the remaining uranium and the plutonium produced, to be used later in other fission reactors. High Level radioactive Waste (HLW), from reprocessing is vitrified for final storage in containers.

ADVANCED CLOSED CYCLE: With transmutation. Still under development especially by France and Japan

In Spain, a definitive decision has not yet been made between the open or closed cycle, but if, as announced, the nuclear program is closed in the coming years, without the need to obtain new fuels from reprocessing, the Open Cycle that requires less investment, will possibly be chosen.

The company ENRESA, since 1984, is the public sector entity responsible in Spain for managing the inventory of radioactive waste in general, produced anywhere in Spain, collecting, treating, conditioning and storing it under the regulations of the approved Waste Plan in Parliament.

Apart from the main and better known use of radioactive materials in nuclear power plants, Enresa manages all other radioactive waste in medical and industrial applications, or those related

SPENT FUEL MANAGEMENT OPTIONS

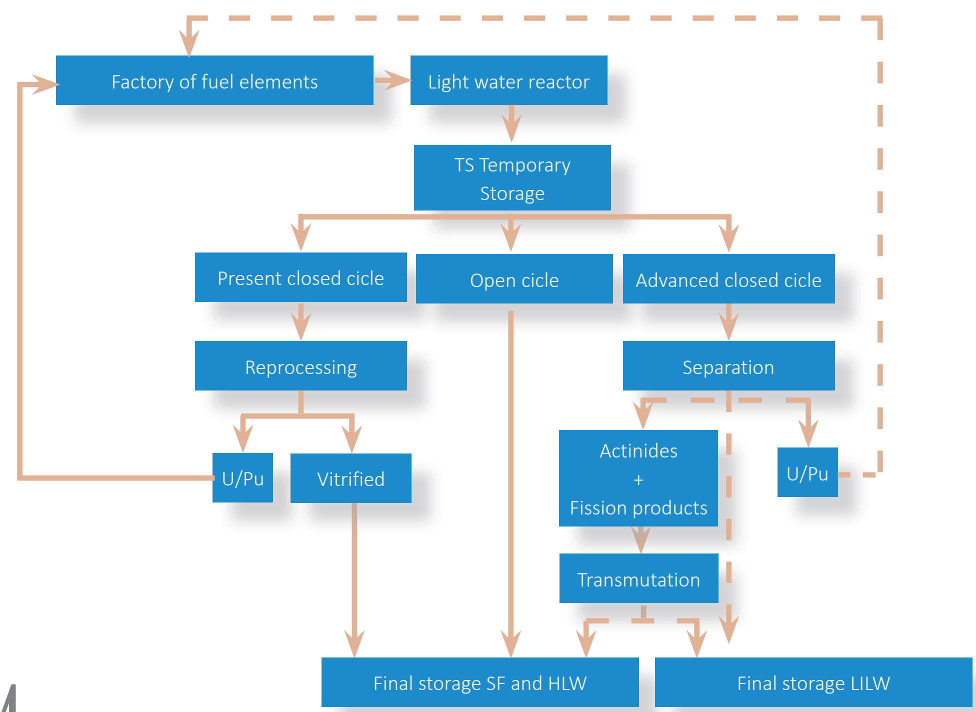


Fig.4 Spent fuel management options

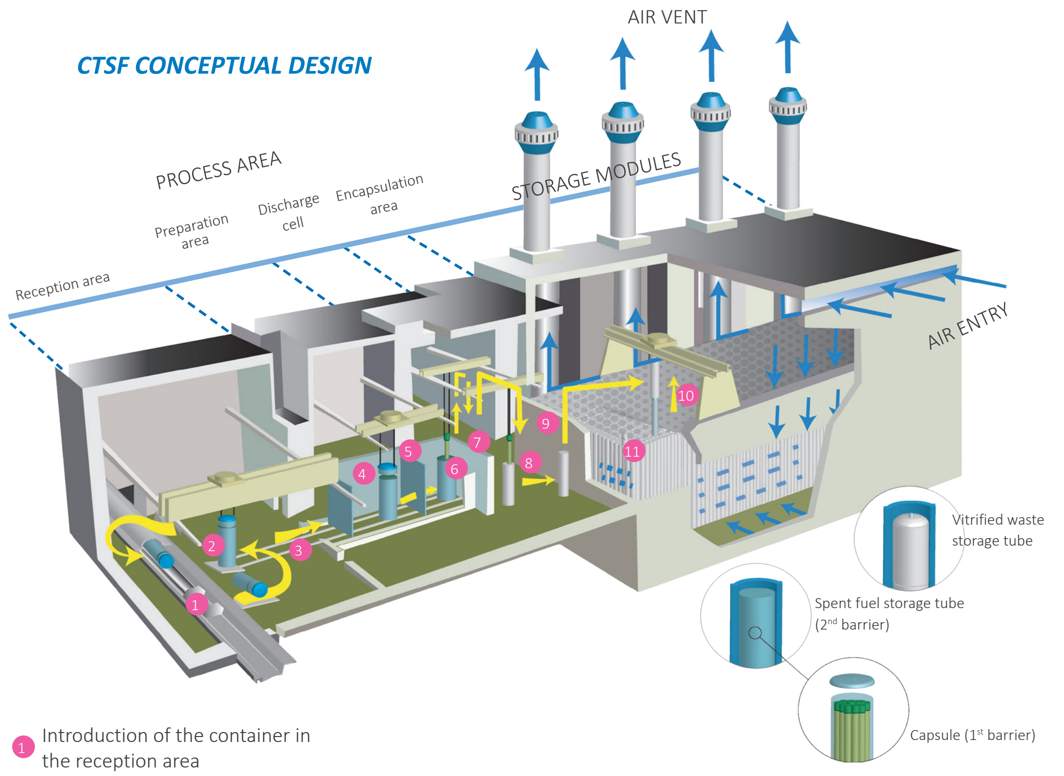
to Research, carried out in authorized facilities, different from the power plants.

The General Radioactive Waste Plan, approved in 2006, established the need for a Centralized Temporary Storage Facility (CTSF), where high radioactive waste can be kept for 60 years.

In 2011, after an evaluation of different locations, the Ministry of Industry preselected Villar de Cañas, Cuenca for its construction, but this decision was finally paralyzed by the Ministry of Ecological Transition, by the opposition of the local goverment "Junta de Castilla-La Mancha" and finally rejected last Feb2020 by ENRESA, with the closing of the contest for the work.

Regardless of whether or not nuclear power is definitively abandoned in Spain in the near future, with a staggered closure of the current plants in operation, the construction of the CTSF in a certain location becomes increasingly urgent, once the temporary storage in the pools and ITS of the plants reach their saturation, while the spent fuels from Vandellós, once reprocessed in France, are already currently subject to penalties for delayed transport and final storage, in Spain, as already vitrified waste of high and medium radiation.

This CTSF will accommodate the radioactive products currently in temporary warehouses, at the plants, the waste that arrives from reprocessing in France, as well as the new ones that are produced until the definitive shutdowns of each plant and



1. Introduction of the container in the reception area
2. Flip the content to the vertial position
3. Transfer cart
4. Removal of the 1st lid and checking the inside of the container
5. Removing the cell cover and the 2nd container lid
6. Unloading of spent fuel
7. Storage area in transit of spent fuel
8. Stainless steel capsule
9. Transferring the capsule to handling container
10. Transfer to storage tubes
11. Storage tubes

Fig.5 CTSF Design, Source Enresa

those produced during their respective decommissioning.

A next step would be a Deep Geological Repository (DGR), in stable geological formations at great depth, which is the internationally accepted solution for the final management of spent fuels and other high and medium wastes.

Stainless steel contributes to the safe storage of these highly radioactive wastes, both in the pools of the power plants, as a manufacturing material for the RACKs, as well as material that is part of the transport and dry storage containers (CASK) in the current ones ITS, and future CTSF.

The following report from the company ENSA shows the various products this company manufactures for the safe storage of these radioactive wastes, and of which stainless steel elements are an important part.

Bibliography and web resources:

https://www.ree.es/en/press-office/news/press-release/2020/03/renewable-energy-already-exceeds-installed-power-capacity-of-other-sources-of-energy-on-the-Spanish-peninsula

https://www.enresa.es/eng/index/activities-and-projects

https://www.boell.de/sites/default/files/2019-11/World_Nuclear_Waste_Report_2019_Focus_Europe_0.pdf