

Máster interuniversitario de física nuclear – FNA II (2017– 2018)

NUCLEAR ENERGY: THE CASE OF SPAIN

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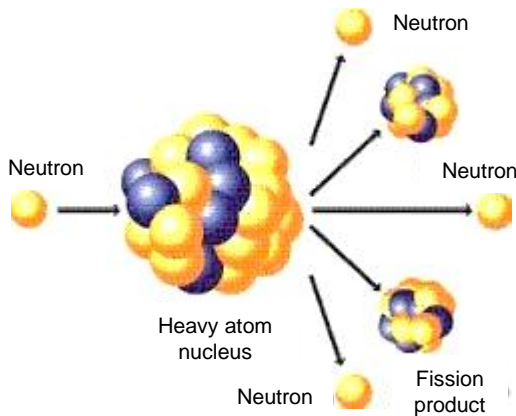
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Introduction

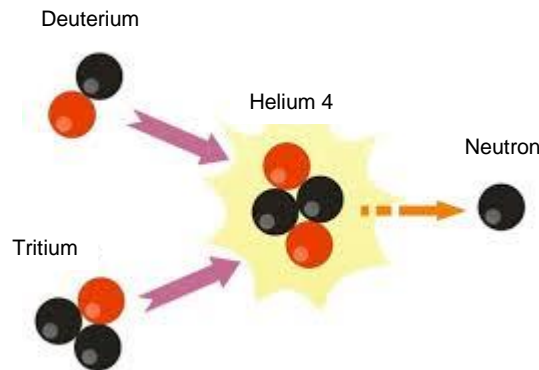
Nuclear Energy usually refers to a wide concept which includes all the knowledge and techniques allowing the use of the energy contained in the atomic nucleus.

This nuclear energy keeps the components of the nucleus together and can be artificially or spontaneously emitted by means of nuclear processes or reactions.

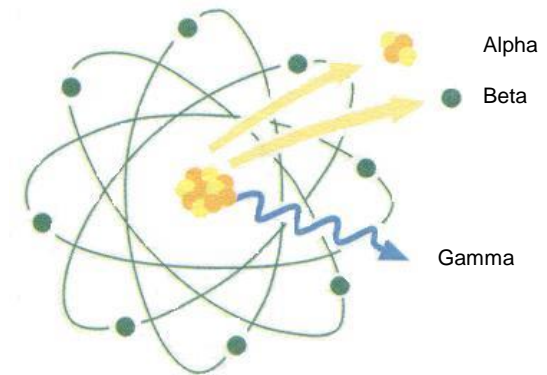
FISSION



FUSION



DECAY



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Evolution of Nuclear Energy in Spain

(I)

The development and evolution that nuclear energy has experienced in an **international and national framework** can be established in the following stages, defined by the historical facts and the successive reactions to them:

[Origin: discovery of radioactivity at end of XIX century ...]

1st stage: Secret and militarization of all the matters related to nuclear energy (1939-1953)

2nd stage: Demilitarization and promotion of the civil uses of nuclear energy in search of its commercialization (1953-1979)

3rd stage: Revision of the nuclear matters under the view of the nuclear safety (1979-nowadays)

Evolution of Nuclear Energy in Spain

(II)

1st stage: Secret and militarization of all the matters related to nuclear energy (1939-1953)

- Discovery of nuclear fission (1938-39)
- Awareness of energy potential: military control of research
- First nuclear reactor in the frame of the Manhattan Project (CP-I, 1942)
- World War II: nuclear bombs in Hiroshima and Nagasaki (1945)
- Spain: no relevance in the field of nuclear physics, it suffered international secrecy
 - National intervention on uranium mining
 - 1947 “agreement” with USA: supply of bibliography on nuclear
 - Creation: [Junta de Investigaciones Atómicas](#) (1948) for high qualification personnel formation, uranium mining exploitation and uranium physics, [Estudios y Proyectos de Aleaciones Especiales - EPALE SA](#) (1949) for geology, mining, physics and metallurgy, [Junta de Energía Nuclear - JEN](#) (1951), rebirth as research center.



Evolution of Nuclear Energy in Spain

(III)

2nd stage: Demilitarization and promotion of the civil uses of nuclear energy in search of its commercialization (1953-1979)

- 1953 United Nations: “Atoms for Peace” declaration -> promotion for commercialization of the peaceful uses of nuclear energy
- Openness of the knowledge on nuclear physics
- Spain: 1955, agreement with USA -> JEN-I reactor (1958), José Cabrera power plant (1968) & Sta. M. de Garoña (1970)
 - Regulation change: Ley de Liberalización del Ciclo del Uranio (1958), Ley Energía Nuclear (1964)
 - Creation of ENUSA (1972)
 - Spain’s membership to international organisms: NEA/OECD, Moscow Treaty (banned nuclear weapon tests in the atmosphere, in outer space and under water), Paris & Brussels Conventions (damage compensation/liability as a result of a nuclear accident)...

Evolution of Nuclear Energy in Spain

(IV)

3rd stage: Revision of the nuclear matters under the view of the nuclear safety (1979-nowadays)

- A nuclear programme is activated in several countries, including Spain
- Concern on nuclear safety (NS) and radiologic protection (RP), nuclear option for energy mix
- Spain: development of regulation on NS-RP, creation of CSN (1980), ENRESA (1984), and CIEMAT (1986)
 - 1983 nuclear moratorium (5 of 7 projects cancelled)
 - 1987 Signature of Treaty on the Non-Proliferation of Nuclear Weapons
 - General Plan on Radioactive Waste (6 up to now, 1987-...)
 - >> El Cabril, ATC



Centrales Nucleares proyectadas

Central	Potencia eléctrica	Tipo	Emplazamiento (provincia)
★ José Cabrera	160	PWR	Guadalajara
★ Sta. María de Garoña	460	BWR	Burgos
★ Vandellós I	4802*930	GCR	Tarragona
★ Almaraz I y II	2*930	PWR	Cáceres
Lemóniz I y II	2*931	PWR	Vizcaya
★ Ásco I	930	PWR	Tarragona
★ Ásco II	930	PWR	Tarragona
★ Cofrantes	975	BWR	Valencia
Santillana	900	LWR	Santander
Punta Endata I y II	2*1000	LWR	Gulpízeua
★ Trillo I y II	2*1000	PWR	Guadalajara



Valdecaballeros I & II (not connected to the grid)

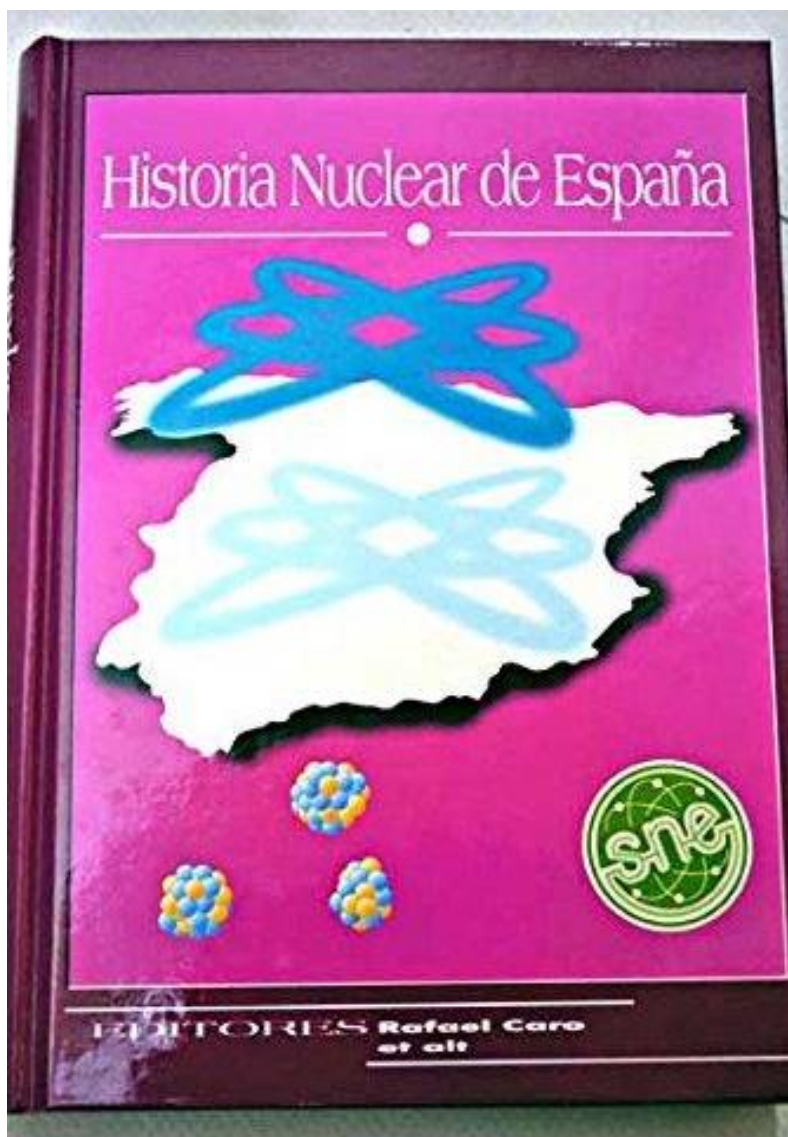


Lemóniz I & II (not connected to the grid)

Sevilla de Electricidad Hidro. Española	BOE 25/11/75		1981/1982
Fenosa/Viesgo/H. Cantabro	BOE 28/08/76		1982
Iberduero	BOE 25/11/75		1981
Iberduero			1985
Iberduero			1988/1999
FECSA/U.E./E.I.A./E.R.Z.			1982/1986
Hidroeléctrica Española			1981
Sevilla de Electricidad			1981/1983
Sevilla de Electricidad H.E.			1980/1990
H.E./H.E./Sevillana			
ENHER/HECSA/Hidroel. Del Sogro/FECSA	BOE 12/03/76		1988
FECSA	BOE 12/03/76		1983

I. Sánchez Ron, ed. CIEMAT 2001

Tabla 1.1



“Historia Nuclear de España”

Rafael Caro et al.

SNE

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Nuclear energy

- The main use of nuclear energy is for the production of electricity by means of fission reactors (fusion reactors are not yet available).
- Currently, there is a significant amount of nuclear energy under construction (Asia and Africa), representing **10%** of the global capacity.
- In **Spain** there are 7 operating nuclear power plants: Almaraz I & II, Trillo, Cofrentes, Ascó I & II, Vandellós I and II, Sta. M. de Garoña and Tróvica. In **2019**, the electricity generated by nuclear power represented **21.4%** of the total electricity produced in the country, and the installed power capacity was **7,117 MWe**.



7 operating nuclear power reactors

5 sites

7,117 MWe net power

6.55 % of total net installed power

Nuclear energy data in Spain in 2019



Leader in electric production

21.43 % of consumed electricity

55,843 GWh net produced



Most hours of operation

90 % of the total hours in one year

7,846 hours of 8,760 in a year



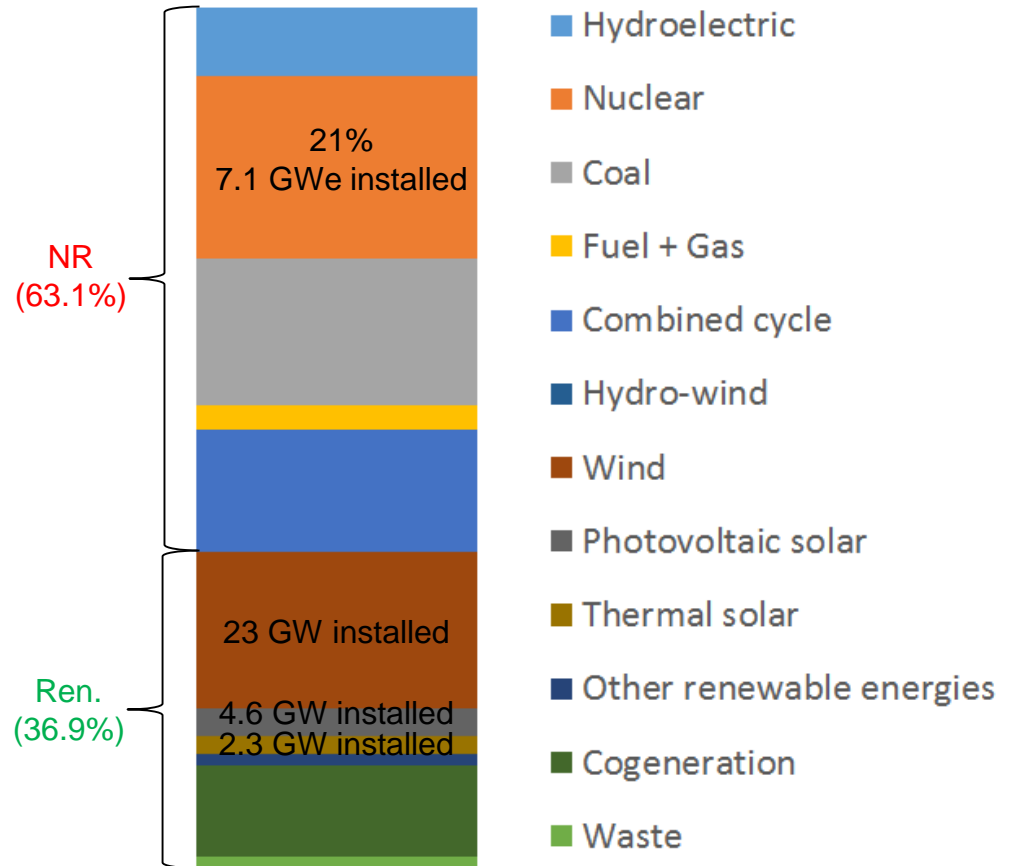
Most emissions avoided

36.22 % of emissions-free electricity

Source: Foro Nuclear with data from REE

Spanish annual electricity balance

2017	
Hydroelectric	20,574
Nuclear	55,612
Fossil Fuels	89,568
Coal	45,199
Fuel + Gas	7,016
Combined cycle	37,353
Renewable and waste	96,911
Hydro-wind	20
Wind	47,886
Photovoltaic solar	8,359
Thermal solar	5,359
Other renewable energies	3,623
Cogeneration	28,182
Waste	3,481
Total generation (GWh)	262,665



Source: Red Eléctrica Española

Spanish nuclear power plants

Reactors	Type	Net MWe	First power	Commercial operation	Owner (%); operator	Licensed to
Almaraz 1	PWR	1011	1981	1981	Iberdrola 53%, Endesa 36%, Gas Natural Fenosa 11%; CNAT	2021/27
Almaraz 2	PWR	1006	1983	1984		2023/28
Asco 1	PWR	995	1983	1984	Endesa (100%); ANAV	2023/29
Asco 2	PWR	997	1985	1986	Endesa (85%), Iberdrola (15%); ANAV	2025/30
Cofrentes	BWR	1064	1984	1985	Iberdrola (100%); Iberdrola	2021/33
Trillo 1	PWR	1003	1988	1988	Iberdrola (48%), Gas Natural Fenosa (34.5%), EDP (15.5%); CNAT	2024/35
Vandellos 2	PWR	1045	1987	1988	Endesa (78%), Iberdrola (28%); ANAV	2027/34
Total (7)		7121 MWe				

Nuclear Power Plants in Spain



	Type	Net MWe	First power	Shutdown	Years of operation
Vandellos 1	UNGG	480	1972	1990	18
Jose Cabrera (Zorita)	PWR	142	1968	2006	38
Santa Maria de Garona	BWR	446	1971	2012	41

Spanish radioactive facilities

Instalaciones nucleares en España, mucho más que reactores nucleares

En España hay cerca de 36.000 instalaciones radiactivas, más del 90% son para uso médico

35.980
instalaciones radiactivas

34.592 instalaciones de rayos X

34.952	755	189	84	7
Total uso médico	Uso industrial	Investigación y docencia	Uso comercial	Reactores nucleares

Potencia bruta instalada (2014)

MW
tipo

PWR: Reactor de Agua a Presión
BWR: Reactor de Agua en Ebullición



REACTOR EN FUNCIONAMIENTO



REACTOR EN DESMANTELAMIENTO



GESTIÓN/ALMACÉN DE RESIDUOS



FÁBRICA DE ELEMENTOS COMBUSTIBLES



Fuente: Ministerio de Industria, Energía y Turismo, CSN y elaboración propia. (1) Desde el 6 de julio de 2013 se encuentra en situación de cese de actividad. (2) Almacén Temporal Centralizado de residuos de alta actividad y combustible gastado, en construcción. (3) Almacén de residuos de baja y media actividad.

Source: Foro Nuclear



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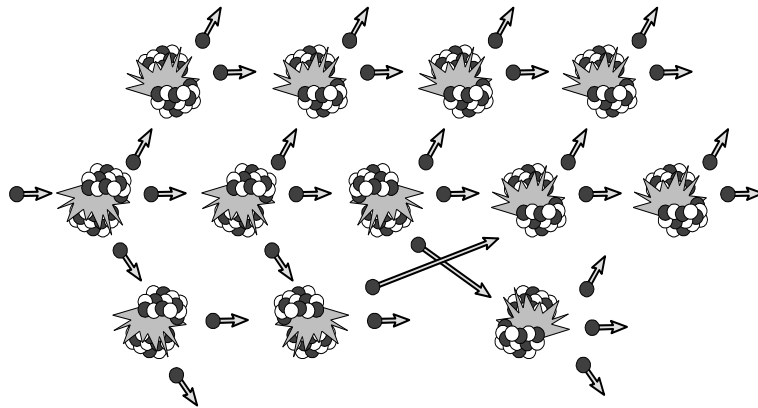
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Nuclear energy (II)

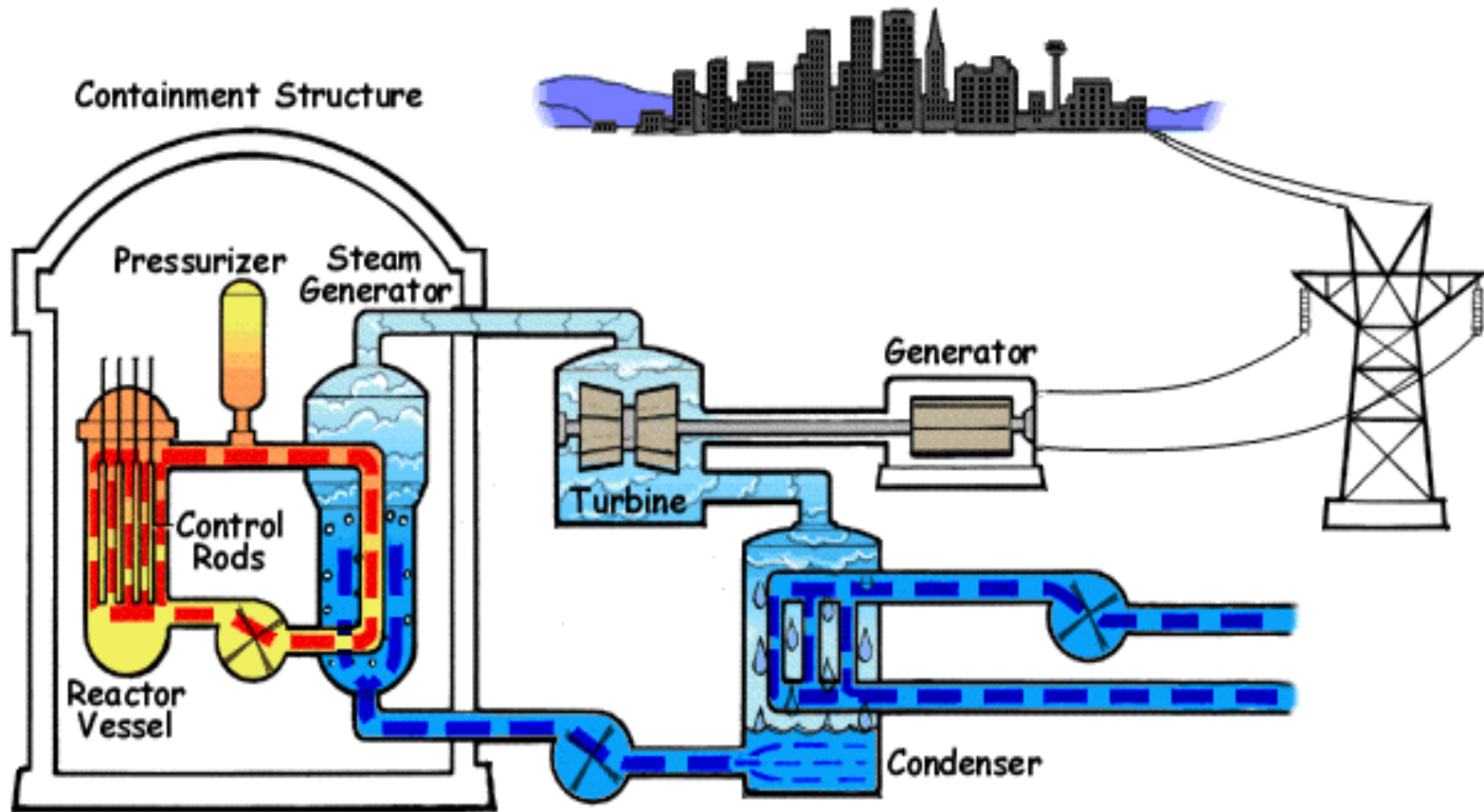
The operation of a **nuclear power plant** is the same that the operation of other power station (coal, oil, gas). Fossil or nuclear fuels produce heat, which is used to boil water to make steam, which is delivered to a turbine.

In the current nuclear reactors, this heat is created by means of **fission reactions** produced in the nuclear fuel: the fission generates heat and other particles (neutrons) with high kinetic energy that can be transmitted to the surrounding media and used to create more fission reactions.



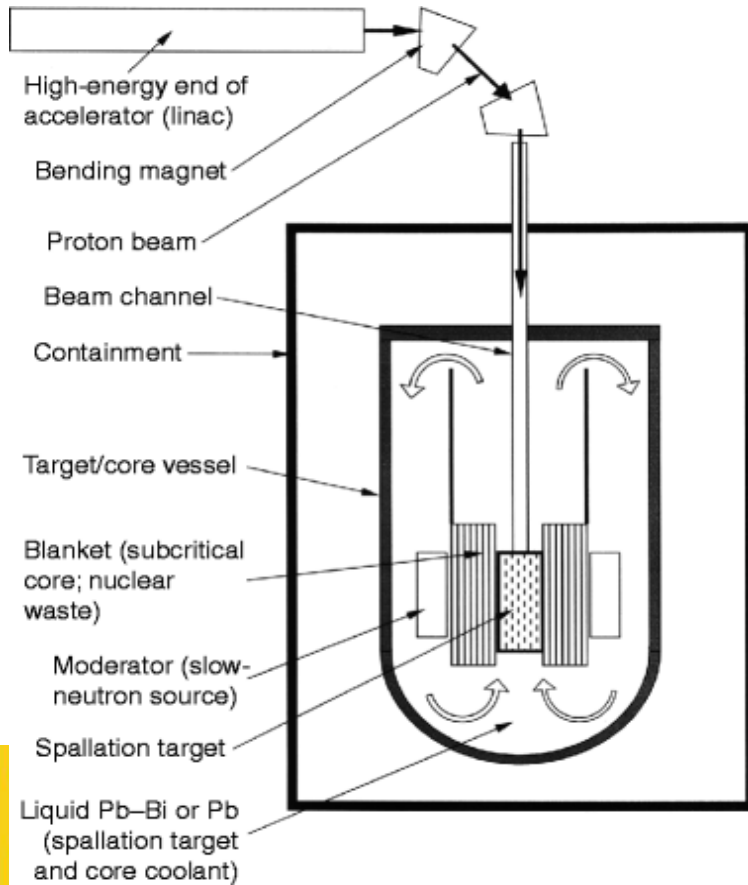
Nuclear energy (III)

General scheme of a Pressurized Water Reactor (PWR)



Nuclear energy (IV)

- **R+D:** The ADS (Accelerator-Driven subcritical System) are nuclear systems where a high intensity accelerator (protons) makes high energy particles collide against an adequate (lead) target producing a large amount of neutrons due to the spallation reaction that can be used for different purposes.

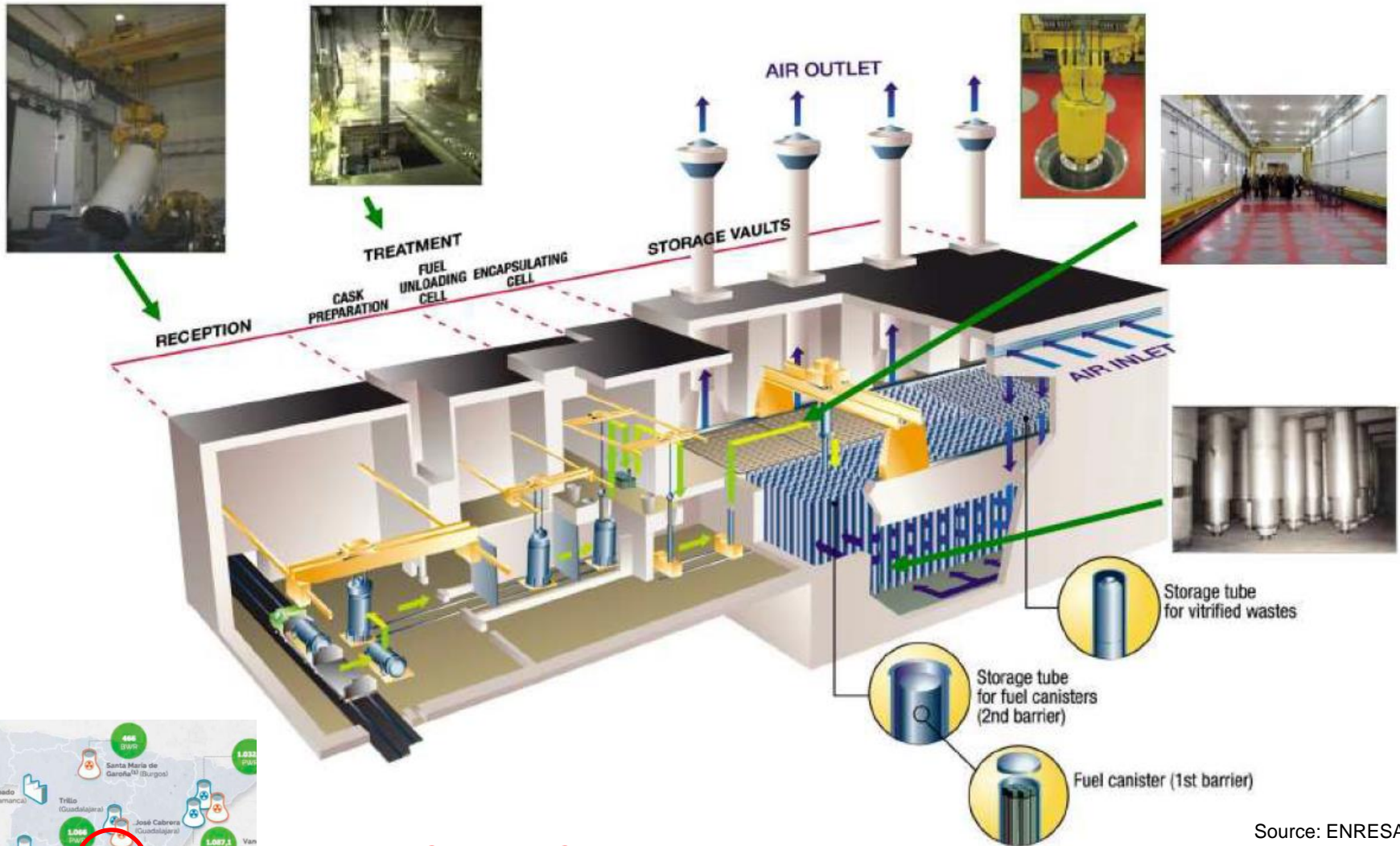


The main purpose of the ADS is the transmutation of high level nuclear waste, changing the long lived radioactive isotopes present in the nuclear waste into other isotopes having a smaller radiotoxicity and a shorter lifetime.

1998 – Project of building and ADS in Zaragoza (Spain): Laboratorio del Amplificador de Energía.

2004 – Project of building a test ADS at the ATC: Almacén temporal de residuos radiactivos.

The Spanish ATC (Centralized Interim Storage)



Villar de Cañas, Cuenca

Source: ENRESA



ATI (Individual Interim Storage)

- Commissioned by ENRESA, in close collaboration with the owners, with the aim of having more flexibility for the final transport of the spent fuel to the ATC.
- Currently there are 5 ATIs in operation and 1 in construction: Trillo (2002), José Cabrera (2009), Ascó (2013), Almaraz (2018), Garoña (2018) and Cofrentes (construction began in 2019). Vandellós pools are at 90% capacity (plan for an ATI commissioned in 2026).
- Their goals are maintaining subcriticality, the confinement of the radioactive material, the removal of the generated residual heat, having capacity for the retrieval of the fuel, the control of the operational, public and environmental exposure.
- All of them are dry storage excepting Garoña.



Ascó nuclear power plant individual interim storage. Source: Spanish YGN

El Cabril disposal facility

- The Spanish disposal facility for very low, low, and intermediate level radioactive waste (El Cabril) is located in Hornachuelos (Córdoba) and is managed by ENRESA.
- It receives radioactive waste from nuclear power plants and radioactive facilities.
- It is divided into two well defined areas: the buildings area and the disposal area.
- The low and intermediate level disposal area is formed by two platforms (north, with 16 disposal structures, and south, with 12).
- The disposal area for very low level waste consists in one platform.



Source: ENRESA



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Most of the Spanish regulation referring to nuclear activities is based on international Treaties and Conventions signed by Spain and EURATOM Directives. Later, these rules are transposed into **national regulation**.

The Spanish Nuclear Safety Council (CSN) is the **sole nuclear safety and radiation protection authority in Spain**. The CSN is governed by public law and by its charter. It is independent from the central government, and it has its own legal personality and its own assets. It is accountable to the Congress of Deputies and the Senate.

The CSN's mission is to **protect** employees, the population at large and the environment from the harmful effects of ionizing radiation. It accomplish this by ensuring that nuclear and radioactive facilities are **operated safely** and by establishing the preventive and corrective measures to apply in all radiological emergencies, no matter what their source.

Spanish regulation

CSN proposes to the government the necessary nuclear safety and radiation protection regulations and any updates to them that the CSN deems advisable. The CSN also adjusts Spanish legislation to comply with international legislation, especially European Union directives.

Similarly, the CSN prepares and approves technical documents for nuclear and radioactive facilities and other activities within the areas for which the CSN is responsible. In particular:

- Instructions, compulsory technical rules on nuclear safety (NS) and radiation protection (RP). They are published in Spain's official journal.
- Guides, technical recommendations for guidance. Not compulsory.
- Circulars are informative technical documents about facts or circumstances related to NS or RP.

Guía de Seguridad 1.19

Requisitos del programa de protección
contra incendios en centrales nucleares

CSN

Colección Guías de
Seguridad del CSN

- 1 Reactores de Potencia y Centrales Nucleares
- 2 Reactores de Investigación y Componentes Subcríticos
- 3 Instalaciones del Ciclo del Combustible
- 4 Vigilancia Radiológica Ambiental
- 5 Instalaciones y Aparatos Radiactivos
- 6 Transporte de Materiales Radiactivos
- 7 Protección Radiológica
- 8 Protección Física
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Nuclear industry in Spain

The Spanish companies related to the nuclear sector are present in all aspects of nuclear power:

- design, construction, operation of nuclear power plants
- energy distribution
- fuel fabrication
- decommissioning/dismantling, waste management
- R&D projects

...all of this to a national and international level



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The Spanish Nuclear Society provides the Nuclear Directory, which includes information of companies, products and services made by Spanish companies.

More than 160 companies and institutions.

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