

New nuclear trends and achievements in France, paving the way for the next decade and beyond

AESJ – March 27th, 2024

V. Dufour, EDF SVP & General Representative, Japan & Korea





CONTENT

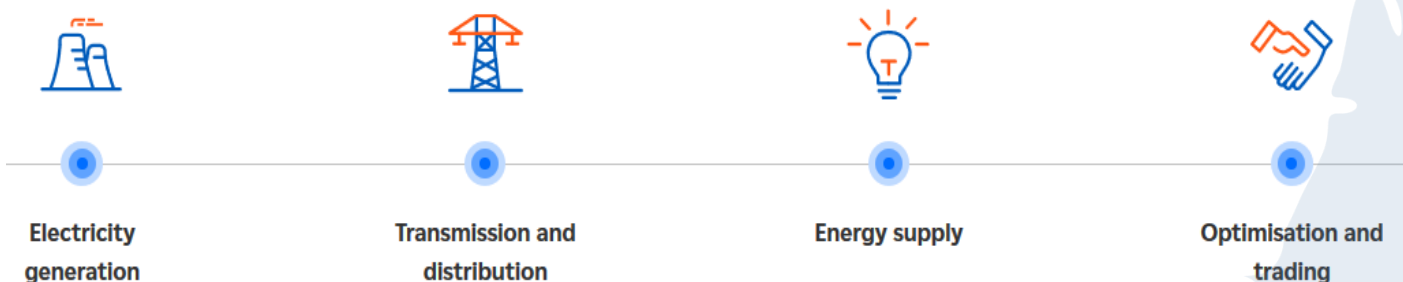
- 01 . Brief presentation of EDF Group**
- 02 . A new momentum : “nuclear is back” in Europe**
- 03. Two main challenges ahead by 2030 : increasing the production of nuclear energy and preparing the ground for the construction of new reactors**
- 04 . The renovation of the existing fleet paves the way for longer use of nuclear power (LTO), which goes with continued progress in decommissioning and dismantling techniques**
- 05. New build and innovative perspectives in France and beyond**
- 06. Conclusion**



Brief presentation of EDF Group

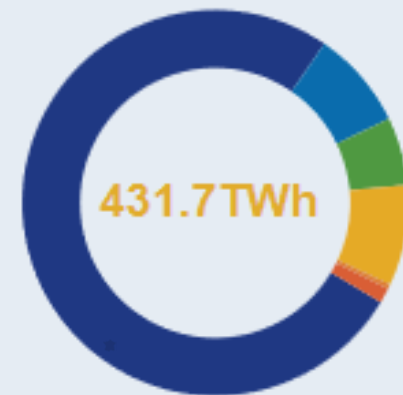
EDF, leading electricity generation and distribution company in France

- The largest distribution grid in Europe and the main distribution grid in France: **connected to 95% of the French metropolitan population**
- Europe's leading electricity exporter with **50,1 TWh net exports in 2023**
- Owning **the largest nuclear fleet worldwide**
- Active across **the whole electricity value chain**



- **With a worldwide presence** in more than 20 countries
- **Group total investment/ year** : circa 20€ bn

EDF ELECTRICITY OUTPUT IN 2022



76%	Nuclear
8%	Hydropower
6%	Other EnR
9%	Gas
0.4%	Coal
1%	Fuel Oil

A world leader in low carbon electricity generation

➤ A carbon neutrality ambition by 2050



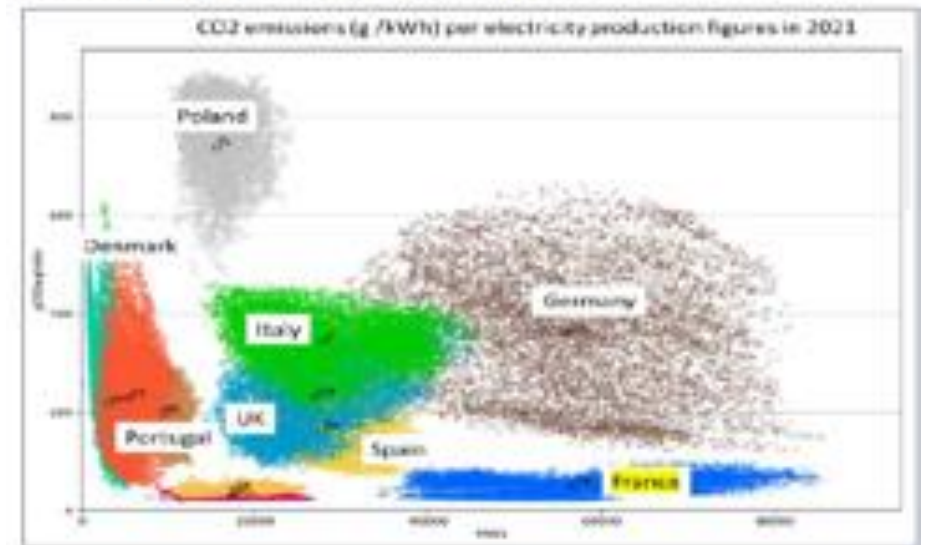
➤ Producing 96% of CO₂-free⁽¹⁾ electricity in France

(1) Direct emissions, excluding life cycle analysis of generation means and fuels

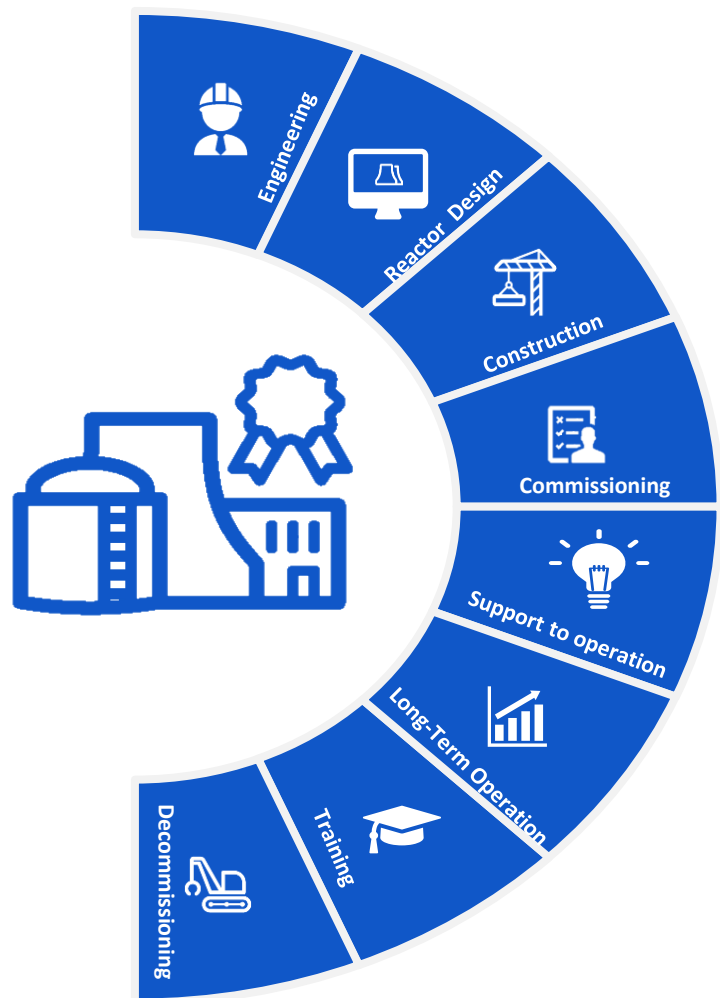
Emissions of 51g CO₂/kWh (world), 36g (in France)

➤ On Sept 15th 2023, **TIME** magazine and Statista survey of 750 companies ranked EDF as **8th best** company in the world for its efforts in decarbonization and **2nd best** in Europe. It is also the leading company in the energy sector.

Thanks to our energy mix, the CO₂ emissions in France are ~14 times lower than the average in Europe



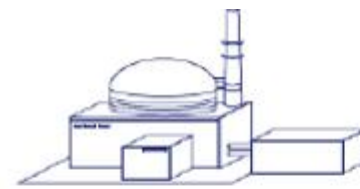
EDF Group : an extensive expertise covering the entire nuclear chain : from existing reactors to new ones



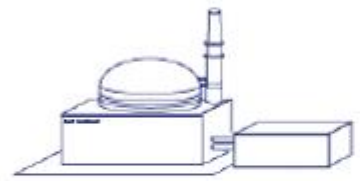
56 reactors
in operation
61,4 GWe
1 reactor under commissioning & close to operation (2024)

9 reactors
in operation
5,9 GWe
2 reactors in construction (HPC)

2 Reactors in operation*
* EDF minority shareholder



EPR
1,650 MWe



EPR1200
1,200 MWe



nuward
340 MWe



2200 reactor-years of operating experience



A new momentum :
“nuclear is back” in Europe

Until recently, nuclear energy, one of the backbone of the EU, was on a downward trend



Nuclear policy has been present from the very beginning of the European Union.

The six founding nations signed the Treaty on the European Atomic Energy Community (Euratom Treaty) in 1957, which is one of the three founding treaties establishing the EU.

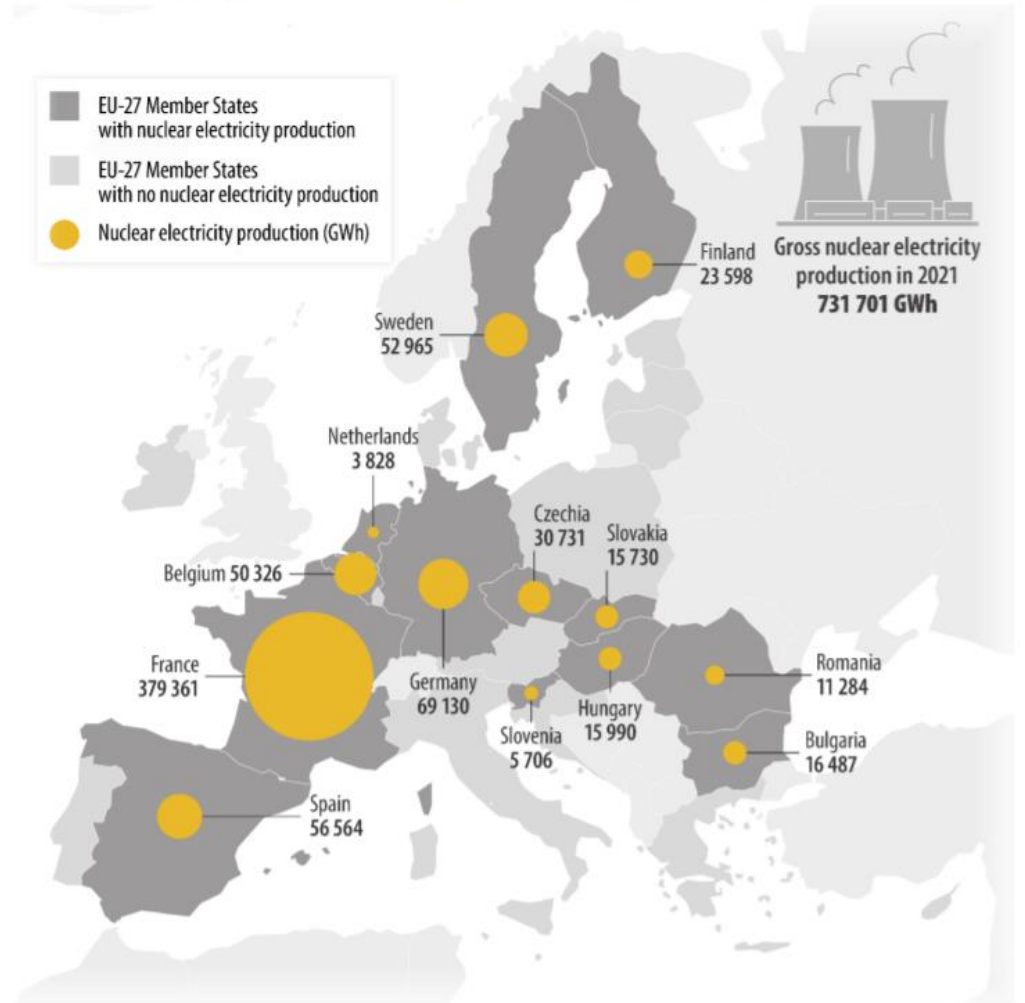


In 2022, the EU's 100 nuclear reactors are operating in 12 out of the 27 Member States. This is a downward trend, as there were 106 reactors in 2021 and 109 at the beginning of 2020.



Over half of the EU's active nuclear reactors are located in France.

Figure 1 – Electricity production from nuclear power in the EU in 2021

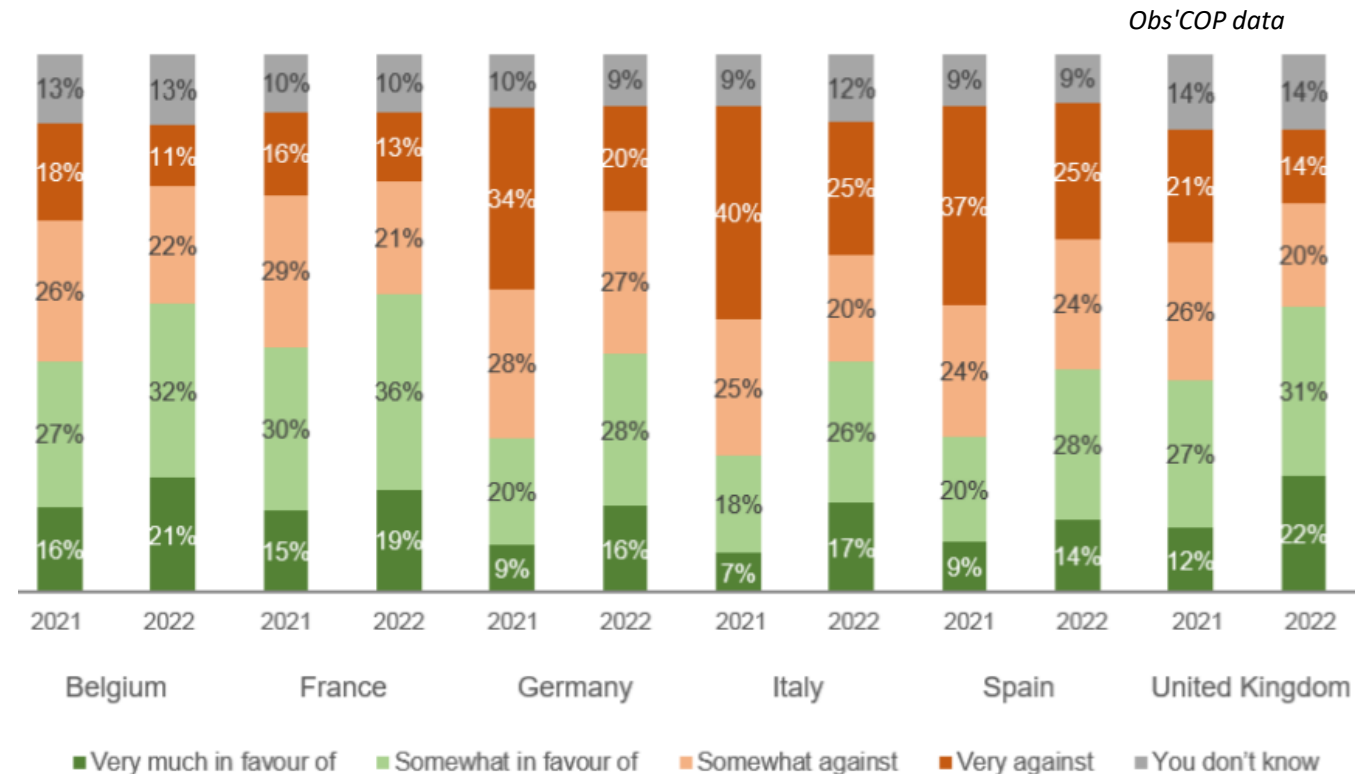


Source: [Eurostat](#), data for 2021 (note that Germany closed its last nuclear power plants in April 2023).

Changing public mindset of some countries in Europe regarding nuclear power

The war in Ukraine, a focal event that is increasing support for nuclear power

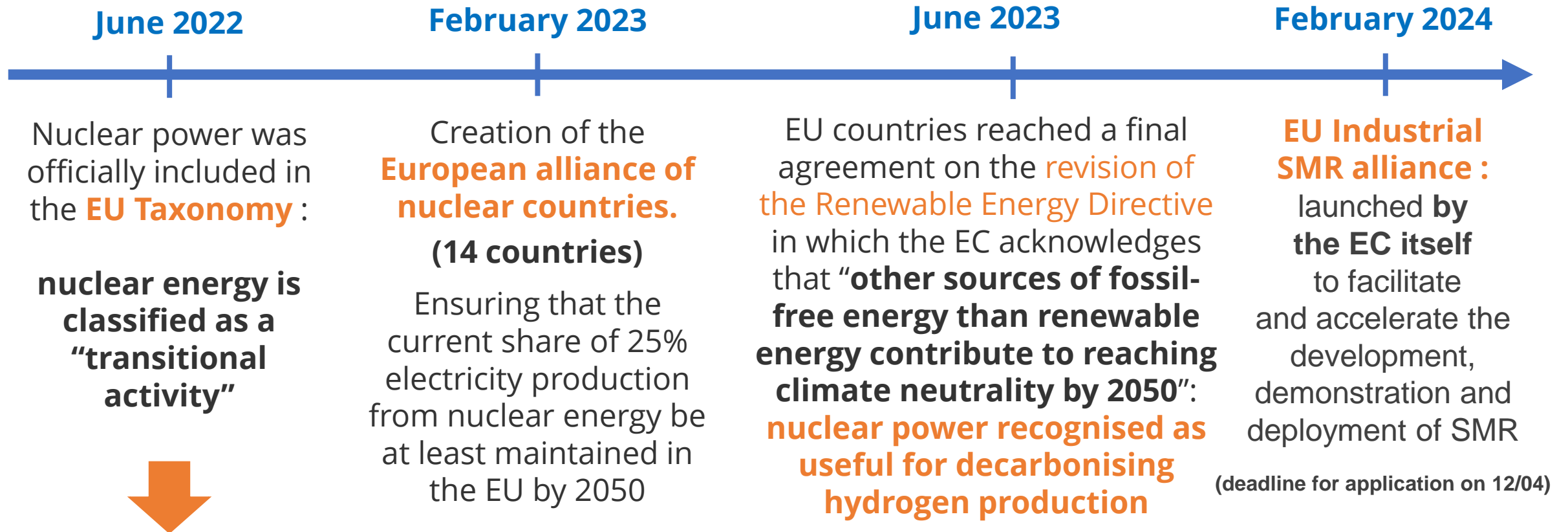
By 2022 there was a **net increase in support for nuclear power, particularly strong in countries where anti-nuclear positions were predominant**, such as Italy (+18 points) or Germany (+15), and more moderate but notable in countries committed to a nuclear phase-out path, such as Belgium (+12 points) or Spain (+13). The UK which is committed to a new nuclear programme, shows a stronger increase (+14) than France, whose support for nuclear power was already high.



About 10 countries, 6 of which are in Central Europe - are building or have announced the construction of new power plants.

In the last 2 years, key milestones have been reached


The EU has progressively recognized that nuclear power is a key source of low-carbon energy



NB: following the adoption of the EU taxonomy, EDF announced an update to its green bond framework which is now including nuclear power generation.

A new momentum for the nuclear industry in France

Recent announcements from the French President and government lead to the following strategy :

- Massive development of renewables energy
- Possible extension of **nuclear reactors lifetime to 60 years of operation and beyond**
- **6 EPR2** will be built (first concrete 2027) and option for the construction of **8 additional EPR2s** by 2050
- **Strong support for SMRs projects**
 - €500M to the **NUWARD™** project PWR led by EDF 
 - €500M to develop innovative reactors
So far eight projects have been awarded (~€20M each):





2 main challenges ahead :

- 1) **Increasing the production of nuclear energy**
- 2) **Preparing the ground for the construction of new reactors by securing the necessary resources and accelerating the procedures**

Maximizing the production of our existing nuclear fleet

> **56 reactors** → In February, 46 of the 56 reactors in the French nuclear fleet were available, representing 50 GW

> **On 18 nuclear sites**

> **Only one technology : PWR**

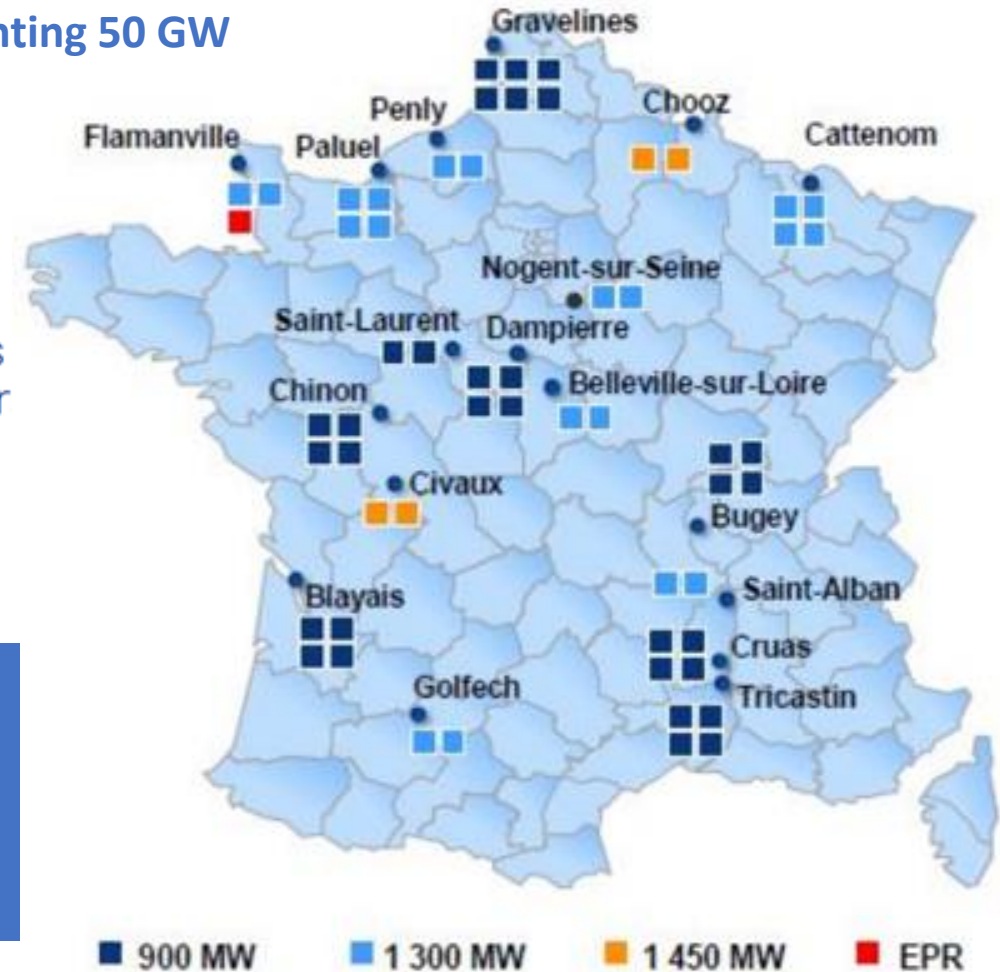
> **3 series :**

- 900 MWe : 32 reactors soit 29 GW – Average age : 39 years
- 1 300 MWe : 20 reactors soit 26 GW – Average age : 33 year
- 1 450 MWe : 4 reactors soit 6 GW – Average age : 21 years

> **One EPR reactor** undergoing construction on the site of Flamanville

In 2022, EDF nuclear generation reached its lowest point since 1988 (**279 TWh**) with half of EDF nuclear reactors off line

In 2023, the increase from 41.4 TWh in nuclear production to **320.4 TWh** reflects a progressive « **back to normal** » situation.



> **Life-time extension of the existing fleet** is now key to meet decarbonization objectives in the long-run

Securing and aligning the necessary resources

- Current situation : **220 000 jobs** related to nuclear activities
- In 2030, around **300 000 jobs** forecasted with this new nuclear program

Circa **10 000 new recruitments per year**

➤ Tools to answer these challenges

- Identification of needed skills (amount and education degree) by industrial companies :
 - **MATCH Program**
- Identification of existing training capabilities and actions to attract people to the nuclear industry :
 - **University of Nuclear Professions**



2022/ 1st move : "The state will assume its responsibilities in securing EDF's finances and its short & medium-term financing capacity"

2023/ 2nd move : a new business model fully compliant with the objectives of the current EU electricity market reform : allowing for better price stability and visibility while providing a competitive electricity price in the long run

➤ On November 2023, the French government and EDF reached an agreement laying the foundations for the **electricity price regulation new model** that will succeed ARENH in 2026.

➤ **This new framework would give EDF an approximate average revenue over several years of around 70 euros (in €2022) per MWh** enabling EDF to make the investments necessary for its industrial projects.

➤ The new system has introduced 2 **deduction thresholds ready to be** activated when market prices reach 78-80 € and 110€ per MWh (additional protection mechanism for customers redistributing a percentage of the additional income made by EDF)

Below € 78 per MWh	€ 78-80 to 110 per MWh	above € 110 per MWh
➤ No deduction threshold Average revenue of 70 euros per MWh over a 15-year period	➤ First deduction threshold 50% deduction rate Between 78-110 euros per MWh	➤ Second deduction threshold 90% deduction rate above 110 euros per MWh



- CAPN contracts (CAPN : Contrats d'allocation de production nucléaire)
- Partnership contract aimed at certain leading manufacturers giving them access to a portion of the power of the existing nuclear fleet
- Optimal contract for large electricity consumers

Accelerating the procedures for New Built projects

“The Nuclear acceleration Act”, a set of measures adopted in June 2023 simplifying administrative procedures and permitting rules



SPEEDING UP PERMITTING FOR NEW NUCLEAR POWER

A set of derogation measures designed to speed up pre-construction procedures and make the issue of permits more secure, including a presumption of "imperative reason of overriding public interest" for new reactors. These measures should lead to significant gains in planning to meet the Belfort objectives.



- **Early start of preparatory work** (earthworks, fencing, car parks) without waiting for the creation authorisation decree, subject to the ASN’s opinion.
- **Reduced litigation deadlines** to limit obstruction of projects
- **Increased penalties** for intrusion into a NPP (up to 2 years' imprisonment and a €30k fine)
- **Simplification of the periodic review process** for reactors beyond the 35th year.



SECURING THE LEGAL FRAMEWORK FOR THE LTO OF THE EXISTING NUCLEAR FLEET

More specific measures to clarify and adjust procedures applicable to existing nuclear sites in France



- **Removal of the 50% limit on nuclear power** in the mix and the 63.2 GW ceiling on installed nuclear capacity



REMOVING THE OBJECTIVE OF REDUCING THE SHARE OF NUCLEAR ENERGY

This measure cancels the limit set in the 2015 Energy Law, of a maximum of 50% nuclear energy in the electricity mix by 2025, then extended to 2035..





The renovation of the existing fleet paves the way for longer use of nuclear power (LTO), which goes hand in hand with continued progress in decommissioning and dismantling techniques

The French context about LTO



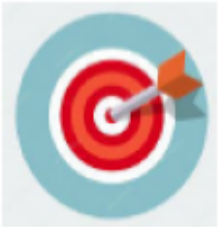
In France, nuclear plant lifetime is governed by decennial periodic safety reviews (PSR). 4th PSR is special because it is the onset of LTO.



In February 2021, French regulator ASN issued a generic position about the operation of 900 MWe PWR Plants beyond 40 years up to the 5th PSR.



It is the outcome of a thorough 10 years preparation that started in 2009, when EDF first announced the launch of a LTO program. This program is now managed by the major refit program “Grand Carénage”.



LTO relies on 3 technical goals:

1. Compliance with safety requirements
2. Aging management
3. Safety reassessment

“Le Grand Carénage”, a major renovation program of the existing fleet

Grand Carénage is EDF LTO program

- pursuing 3 main objectives
- deploying 3 categories of actions



ALLOW
CONTINUED
OPERATION
OF THE CURRENT
NUCLEAR FLEET BEYOND
40 YEARS

ENABLE
THE FLEET TO SAFELY
REACH
ITS GENERATION
TARGETS

MAINTAIN AND
OPTIMIZE
THE FINANCIAL
TRAJECTORY
OF CAPEX INVESTMENTS
AND EXCEPTIONAL
MAINTENANCE
OPERATIONS

- **Projects for periodic safety reviews:** allow each reactor to pass the ten-year milestone by meeting legal requirements and advancing safety.
- **Projects for responses to external hazards:** the goal is to strengthen the nuclear facilities to make them robust to a significantly higher level of external hazards (earthquakes, floods, fires, storms, etc.). Post-Fukushima experience feedback has been taken into account in this category of projects.
- **Replacement and refurbishment of major components** reaching the end of their technical lifetime (exceptional maintenance), such as steam generators and turbine generator sets.

➔ **2014-2028 Financial Trajectory**
€65 bn operating

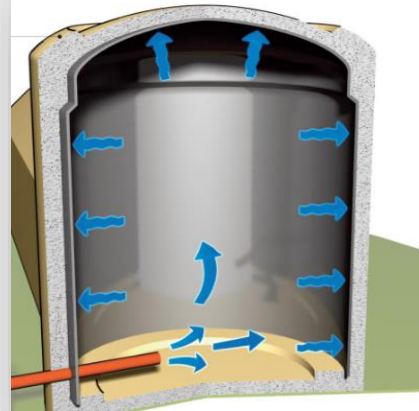
EDF'S CONVICTION IS THAT
THERE IS NO TECHNICAL
DEADLOCK ON OPERATING
FRENCH REACTORS BEYOND
60 YEARS

Beyond 60 years, EDF major Research areas

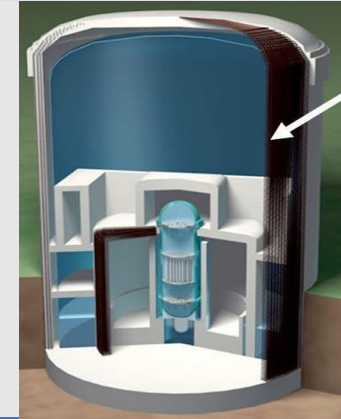
Non
replaceable
components



Vessel



Containment



Vessel Pit

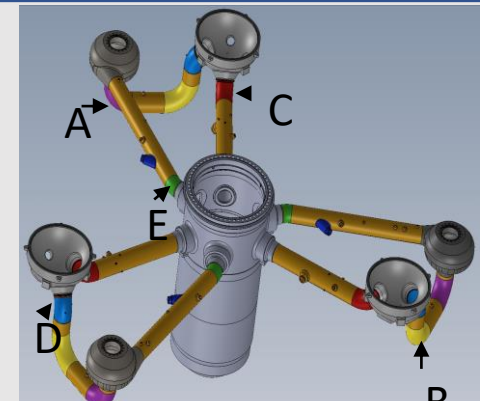
Hard-to-replace
components



Cables



Internals

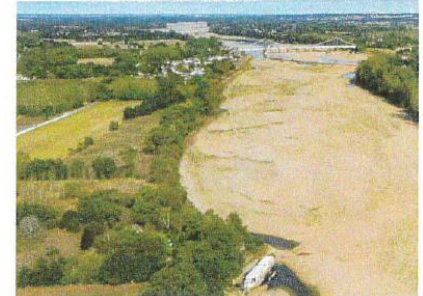
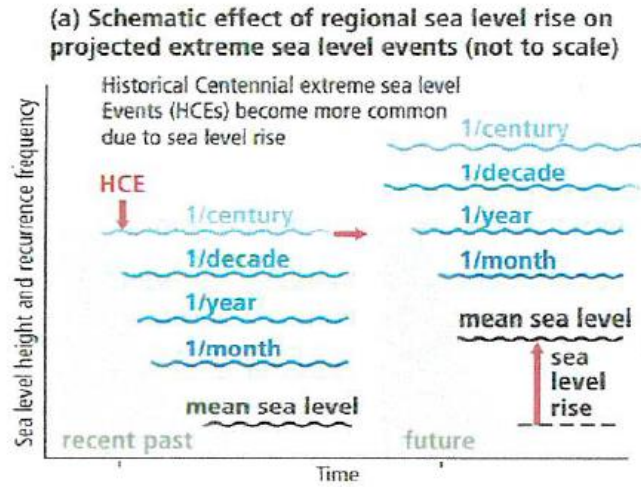
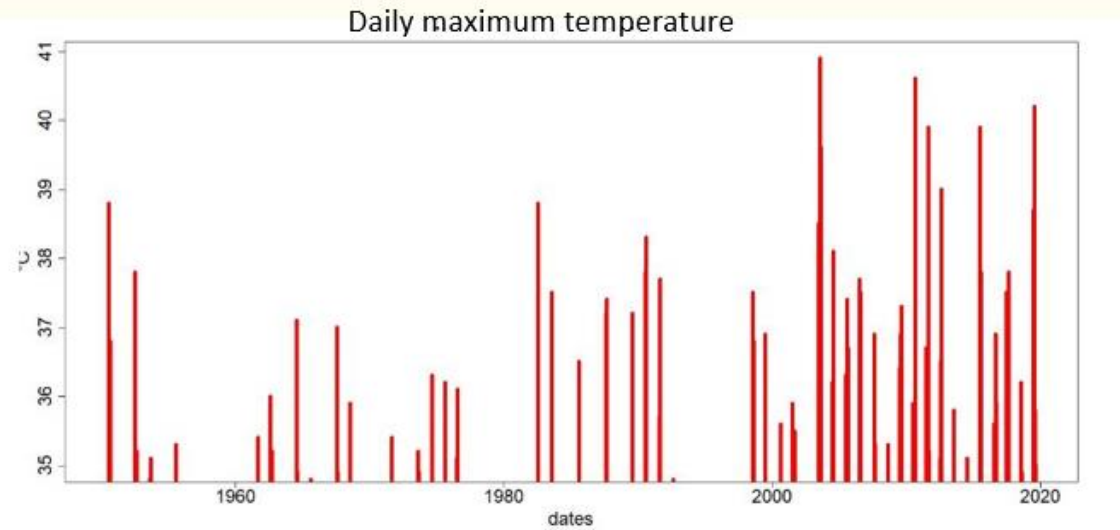


CASS E Elbows

“ADAPT” program, anticipating new risks induced by climate change

Hot temperatures are becoming hotter and more frequent:

In France, the increase of temperatures has reached 1.7°C since 1900 and has accelerated in recent decades. High thresholds (like 35°C here) are more frequently exceeded. The frequency, intensity of heat waves will continue to increase.



Drought – The Loire River Summer 2022
Floodings – Corsica



The water cycle will be disrupted : higher water temperatures, longer and more severe low-water periods, more intense rainfall particularly near the Mediterranean Sea. Rising sea levels will also generate new risks.

Need to take climate change into account to estimate near or further future extremes



EDF Decommissioning and dismantling of EDF reactors

11
REACTORS UNDER
DISMANTLING IN
FRANCE

4
DIFFERENT
TECHNOLOGIES

7
INDUSTRIAL SITES

EDF is committed for the D&D of its shut-down reactors

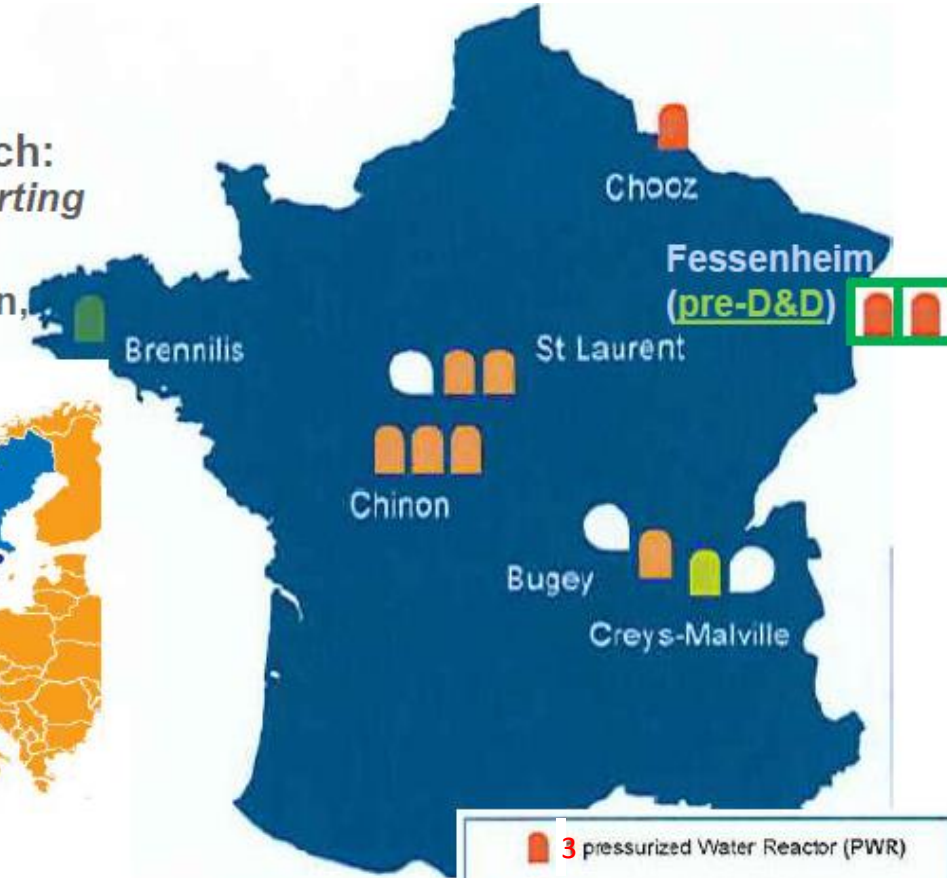
The strategy for D&D is based on **waste-led decommissioning approach**:
 → The definition and implementation of optimized waste routes, *before the starting of the dismantling* to improve the project schedule and cost effectiveness.

→ EDF benefits from its dedicated waste treatment facilities (Cyclife Sweden, Cyclife UK and Cyclife France)

EDF relies also on Cyclife for D&D engineering and innovative processes (including DX)

The liberation of material below the clearance threshold allows to **reduce the volume and mass of waste of large equipment (Steam Generators ...)**

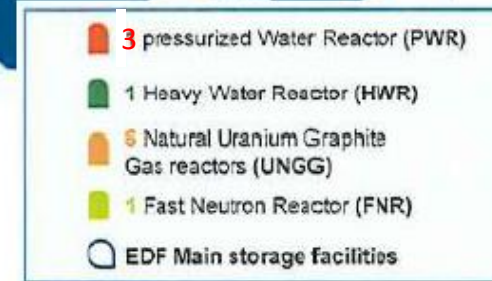
→ Already in place in Sweden and possible in France since April 2022



Mass balance
(Up to 80% recycling)



Volume reduction
(90% reduction of disposal volume)





New build and innovative perspectives in France and beyond

The 1st phase of the New Build Programme is on track in France

➤ An ambitious programme of new nuclear to:

- Ensure a **reliable production base, factor of decarbonization of the economy and security of supply, at an affordable cost**
- **Leverage a competent industrial sector**, recognized internationally and aiming for excellence
- **Ensure France's energy sovereignty.**



EPR

1,650 MWe



- Most powerful reactor in the world
- The leading reference for very high energy demand
- High maneuverability

➤ A 6 to 14 EPR2 will be built on existing sites :

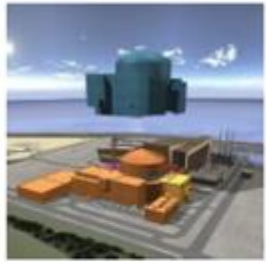
- The first unit delivering power from 2035 will be at Penly (Normandy)
- 2nd and 3rd sites have already been selected : at Gravelines and Bugey
- Ongoing studies on the construction of additional EPR2 reactors



Preliminary site works are set to start by the beginning of next year at Penly

An EPR2 fleet series, with a 1st programme of 3 pairs that would be built within a 3-to-4 years interval between pairs & 18-month interval between reactors in the same pair

EPR: a proven technology derived from decades of expertise and lessons learned from past and on-going EPR projects



Double-wall containment building with a shell able to resist to an airplane crash



4 independent safeguard systems



Core catcher in case of an accident



EPR technology

➤ Safety

- Accident probability reduction (factor 10)
- External hazard protection (shell able to resist an airplane crash)
- Evolutionary design (core catcher)

➤ Performance

- Annual generation boosted of 36%
- Efficiency improvement (+3pts)
- Increased availability (91%)

➤ Radioprotection

- At least 40% cut in collective annual exposure

➤ Environment

- Very important reduction in radioactive waste and gaseous and liquid discharges

Electrical power output	1650 MWe
Thermal power	4590 MWth
Primary system	4-loops configuration
Plant design availability	≥ 90 %
Operation cycle length	12 to 24 months
Design service life	60 years
Instrumentation & Control	Fully digital
Fuel assemblies in core	241 with 17x17 AFA 3G design

EPR2 improvements

Product industrialization	<ul style="list-style-type: none"> • Standardizing components • Reinforcing supply chains • Involving suppliers early in design & execution planning
Strengthening engineering efficiency	<ul style="list-style-type: none"> • Taking benefit from digital engineering
Design optimization to secure delivery	<ul style="list-style-type: none"> • Extending prefabrication • Developing new construction technics • Involving construction and erection companies early in design & execution planning

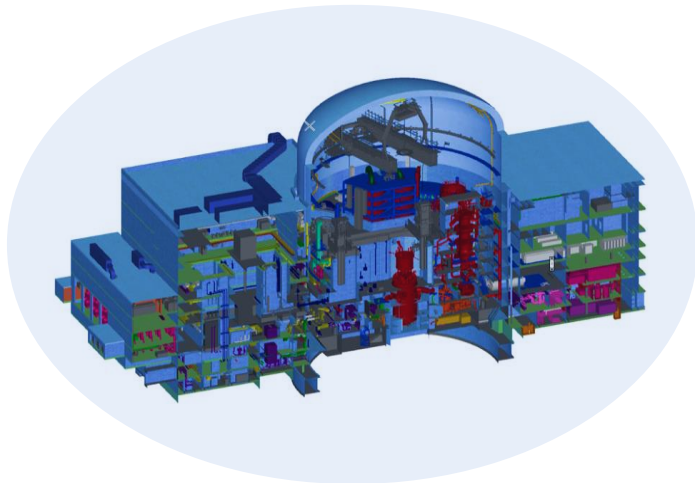
EPR1200, the EPR technology at 1200 MWe of net power output



EPR1200
1,200 MWe

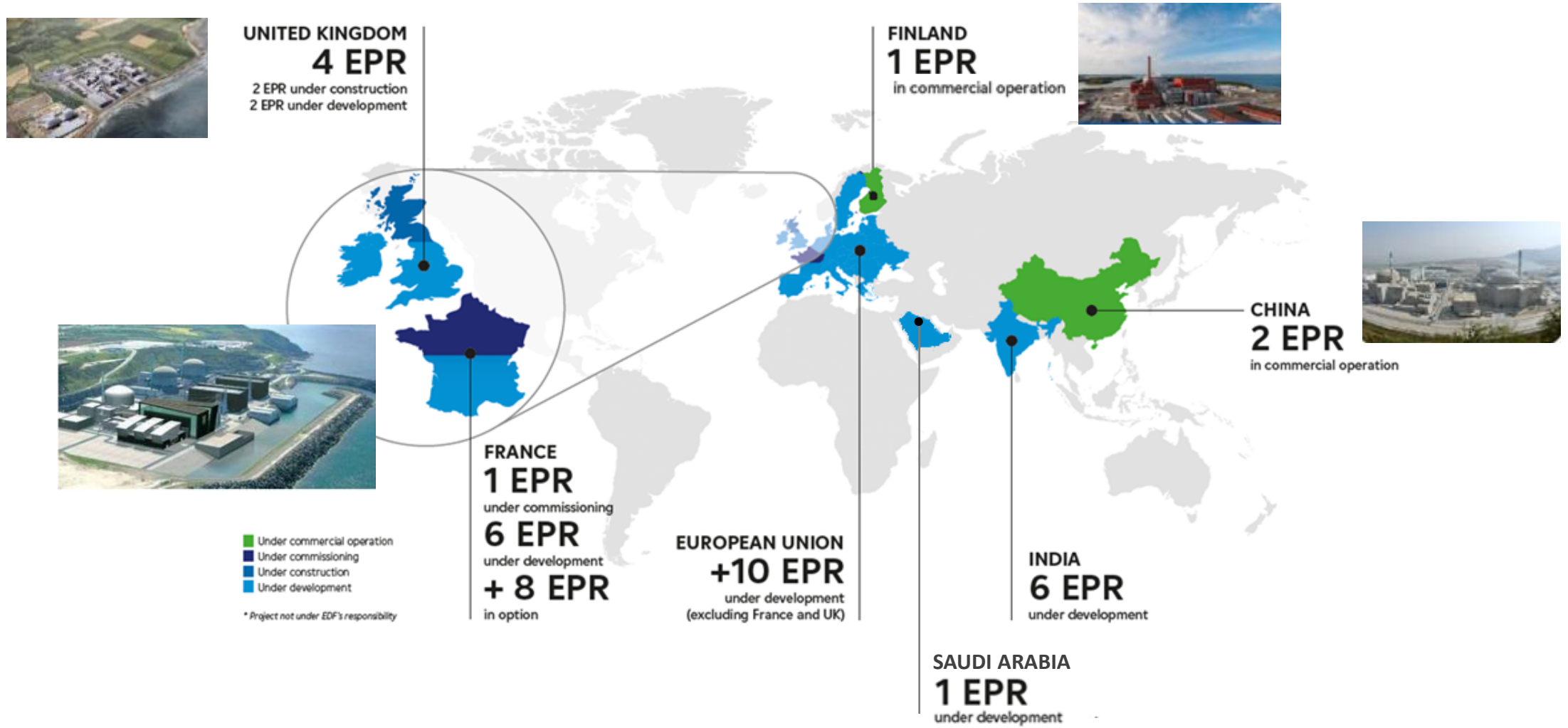


- EPR adaptation to 1200 MWe
- Adapted to various site and grid conditions
- High maneuverability



Electrical power output	1200 MWe
Thermal Power	3300 MWth
Primary system	3-loops configuration
Plant design availability	≥ 90 %
Operation cycle length	18 months
Design service life	60 years
Instrumentation & Control	Fully digital
Fuel assemblies in core	177 assemblies (14ft)

A perspective for up to 30 EPR projects across the world



EDF is fully engaged in nuclear new build activities and is committed to supporting several countries in their nuclear program development with a focus on Europe and India

At EDF we believe that there is some room for a European PWR SMR in the next decade

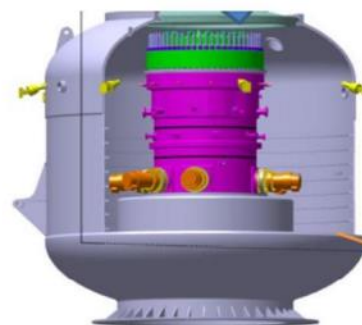
Integrated and modular design with the highest level of safety, to provide a standardised / competitive offer



- Adaptable to various environments
- Other low-carbon use: hydrogen, heat & electricity cogeneration, district heating, water desalination
- High maneuverability



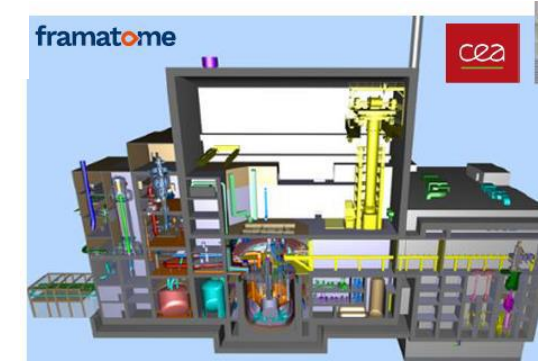
Joint Early Review (JER)



Electrical power output	2 x 170 MWe
Thermal Power	2 x 540 MWth
Primary system	Integrated primary loop
Plant design availability	≥ 90 %
Operation cycle length	Up to 24 months
Design service life	60 years
Instrumentation & Control	Fully digital
Fuel assemblies in core	76 assemblies

The French nuclear industry is developing advanced reactors :

- Fast Neutron Reactors for optimized closed nuclear fuel cycle
- High Temperature Gas Reactors for alternative use of nuclear energy (heat, hydrogen...)
- Molten Salt reactors to burn actinides and reduce volume and radiotoxicity of waste



Framatome 150MWe
Fast Breeder Reactor design

New reactors innovation programme : AMR with Gen4 concepts or fusion

- Projects granted through a competitive process (having 3 phases from concept maturation to prototyping)
- First phase closed in June 2023
- Promoting the emergence of new players (start-ups) in the French nuclear energy sector
- Leveraging public funding with private funding
- Aiming at a partnerships by connecting start-ups and established market players



- **HTR type Reactor**
- **150 MWth**
- Industrial heat and electricity



- **PWR type reactor**
- **30 MWth**
- District heating

Jimmy

- **HTR type reactor**
- **15 MWth**
- Industrial heat



- **Sodium cooled fast reactor**
- **400 MWth / 150 MWe**
- Industrial heat and electricity



- **Molten salts reactor**
- **80 MWth / 40 MWe**
- Industrial heat and electricity

newcleo
Futurable Energy

- **Lead cooled fast reactor**
- **30 or 200 MWe**
- Electricity, heat, radio-isotopes



- **Sodium cooled fast reactor**
- **110 MWe**
- Industrial heat and electricity



- **Fusion type reactor**
- **1GWe**
- Electricity



Conclusion:

- **The French nuclear industry is mobilized and ready to embark on a new cycle, with strong public and political support.**
- **This support needs to be consolidated over the long term, not just in France but at European level and beyond, by building more and more bridges with countries and players facing the same challenges (first and foremost Japan).**



THANK YOU

ありがとうございます

