Nuclear Safety Challenges
Perspective from France

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DE LA RECHERCHE À L'INDUSTRIE

cea

Nuclear Power Plants in France

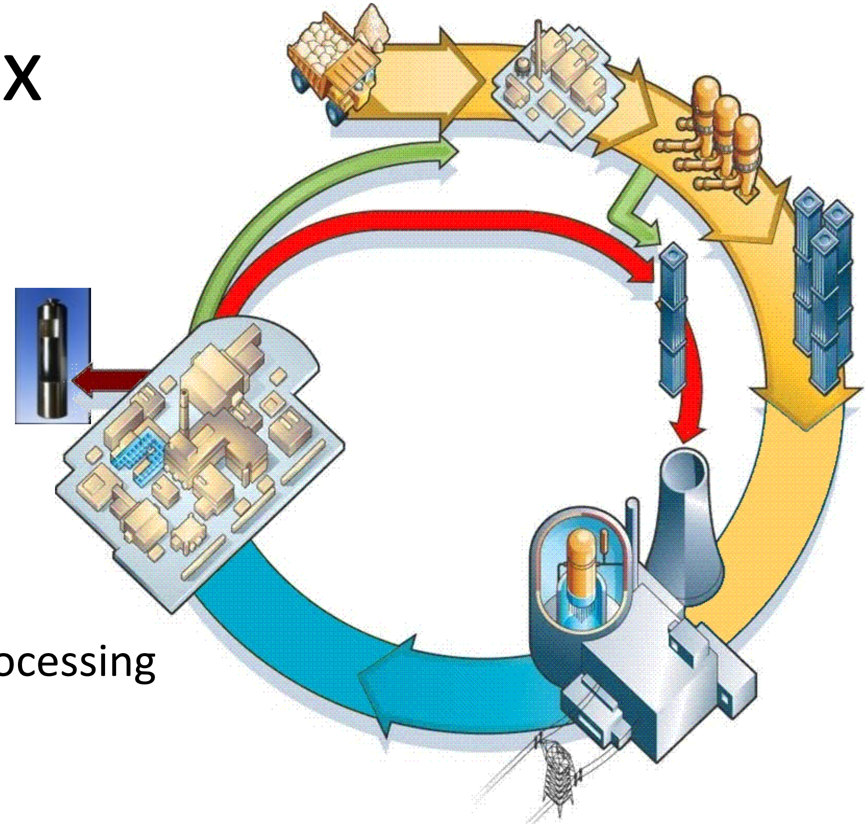
- 58 PWR units on 19 sites
- Installed capacity : 63.1 GW
  - 34 PWR 900 MW
  - 20 PWR 1,300 MW
  - 4 PWR 1,500 MW
- 1 PWR EPR under construction
- 10 reactors under dismantling
- 2000 reactor-years of experience
- 10 Research reactors

about 75% of electricity from nuclear energy (403.7 TWh) due to a long-standing policy based on energy security. This share may be reduced to 50% by 2025.

About 17% of France's electricity is from recycled nuclear fuel

World's largest net exporter of electricity, €3 billion per year from this.

French Nuclear Complex



Institutional Structures:

- Ministries
- Independent Safety Authority ASN
- TSO : IRSN
- Waste management: ANDRA

Industrialists

- EDF: owner/operator/architect
- AREVA reactor constructor, fuel and reprocessing
- sub-contractors
- 125 000 direct jobs in France

R&D: CEA, CNRS, Universities

Educational Institutions: Universities, Engineering Schools

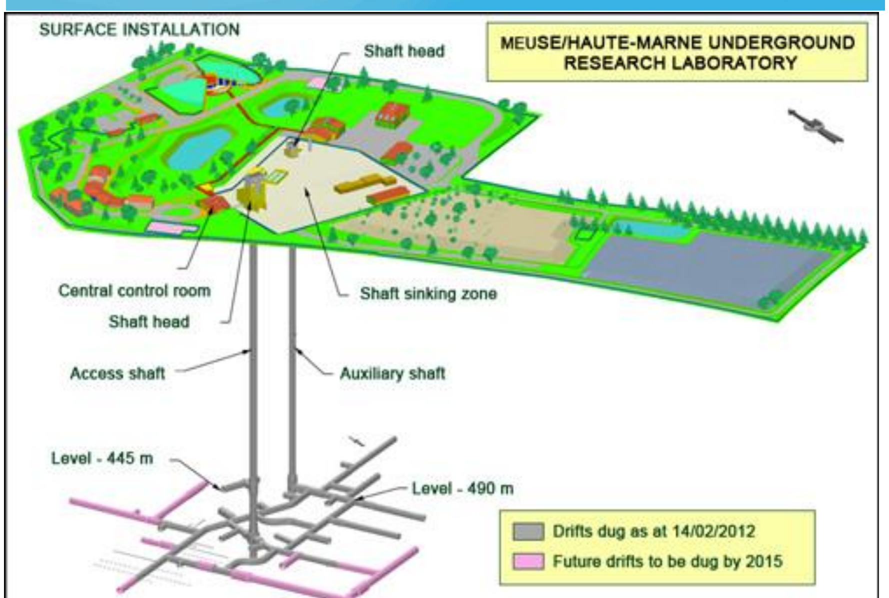
One concept (PWR), one constructor, one operator →

- industrial efficiency
- feedback on past experience
- safety

Fuel Cycle from Mining to Waste Disposal

Georges Besse II enrichment plant (AREVA)

La Hague spent fuel reprocessing plant (AREVA)



Cutaway view of the Bure laboratory
underground laboratory situated at depths of 445 and 490 m in a layer of Callovo-Oxfordian argillite.
The laboratory studies the chemical reactions, mechanical effects and circulation of water that could bring radioelements back up to the surface.
ANDRA

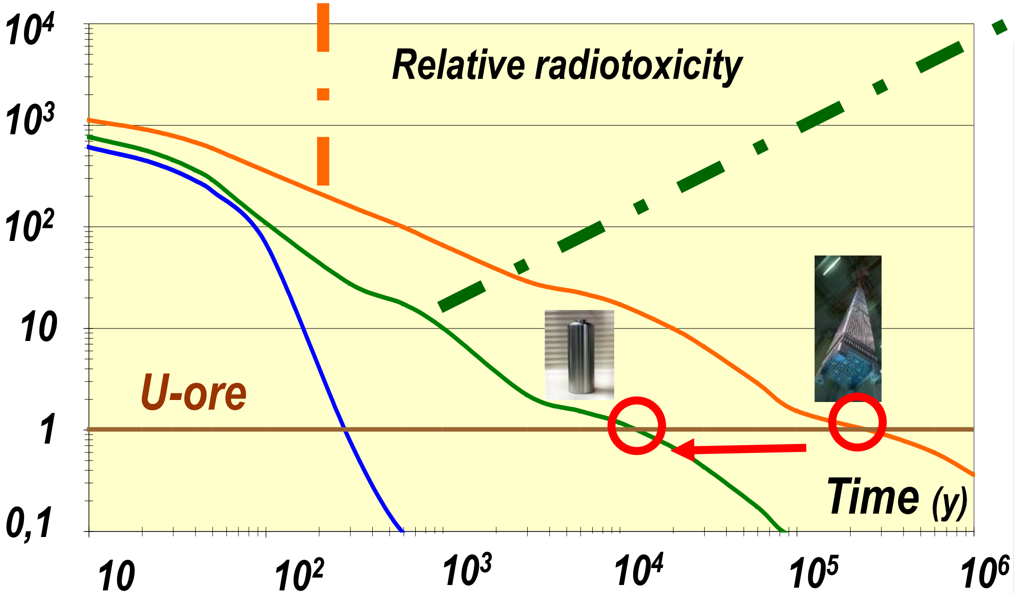
Recycling the spent fuel

La Hague

Uranium & Plutonium

96%

Fission Products &
Minor Actinides
4%

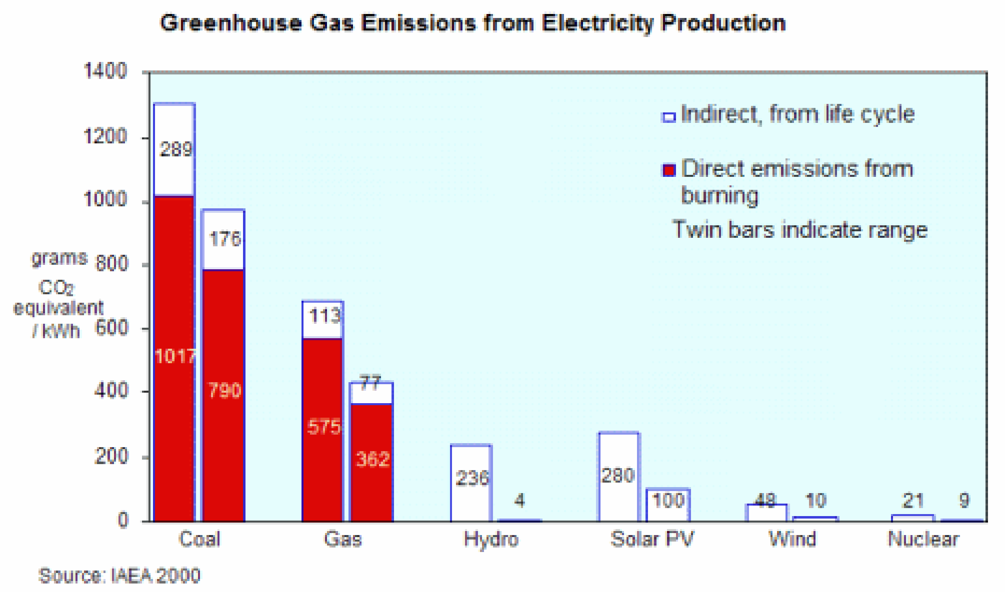


- Current processing process (PUREX) implemented in France in La Hague**:** Allows recovering 99,9% of U and Pu
  ➔ 96% of spent fuel
- Significant improvement for waste management
  - Divide by 5 waste volume
  - Divide by 10 waste toxicity
  - Decrease by >10 waste lifetime

Will Nuclear Energy remain a viable source of electricity ?

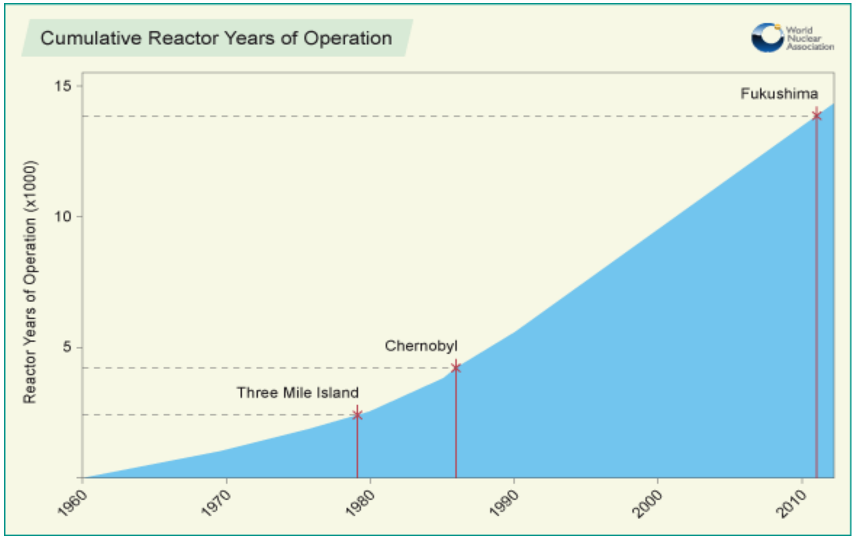
❑ **Reliable carbon free base load**

to ensure continuous electricity production in complement to intermittent renewable energies



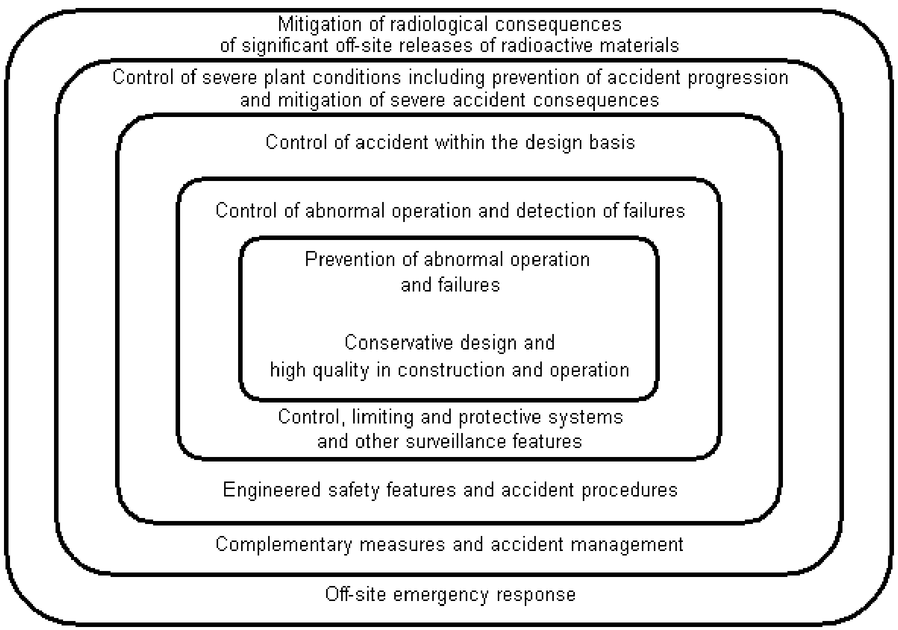
❑ ***However, it is raising concerns***

- *Availability of Resource*
- *Safety of NPP*
- *Waste management*
- *Nuclear weapons proliferation,*
- *Initial capital investment,*
- *Public acceptance,*

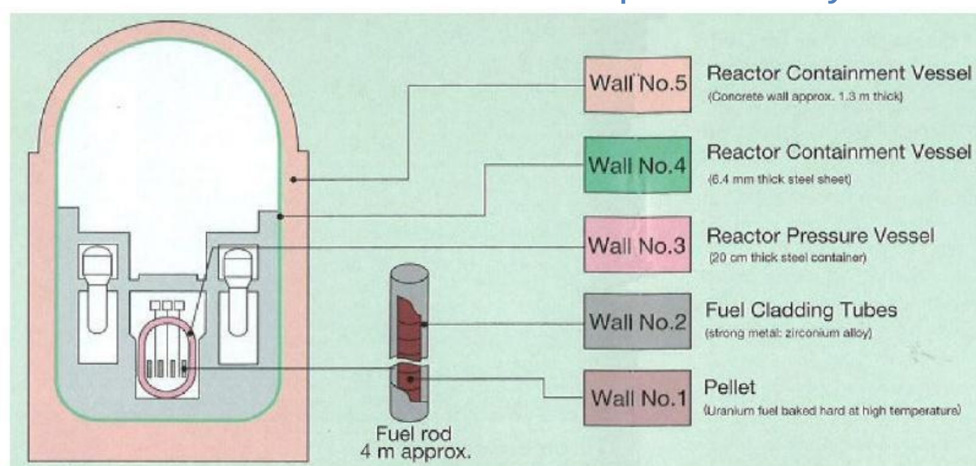


Nuclear Safety Basic Concept : Defence in Depth

- D in D applies to the design, construction, operation, dismantling of the facility
- it is assumed that accidents may still occur,
- Barriers are designed and installed to ensure that consequences are limited to a level that is acceptable for both the public and the environment



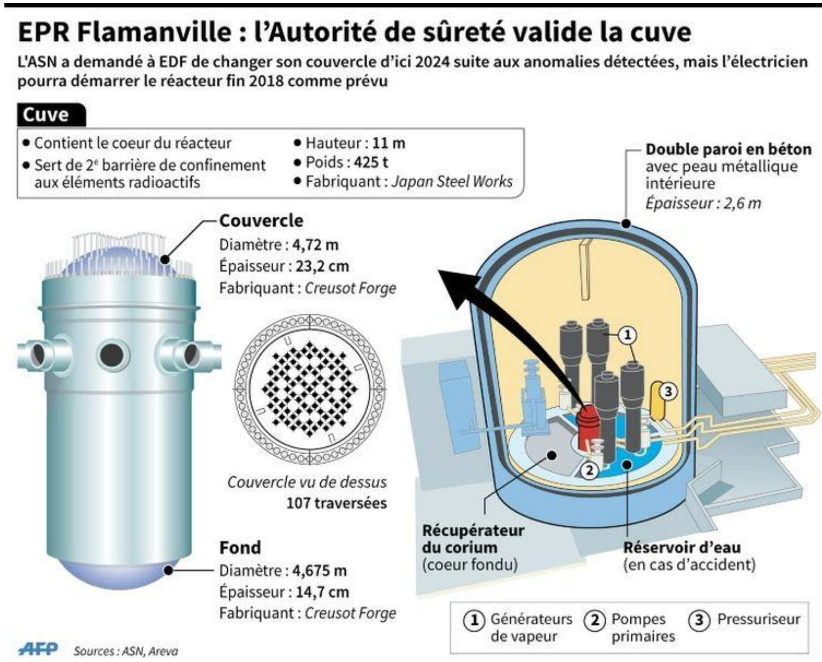
Provision of leaktight "barriers« between the radioactive source and the public. They are



Five Walls of Protection

Safety characteristics of Gen III EPR reactor

Design in terms of Safety has relied on three pillars

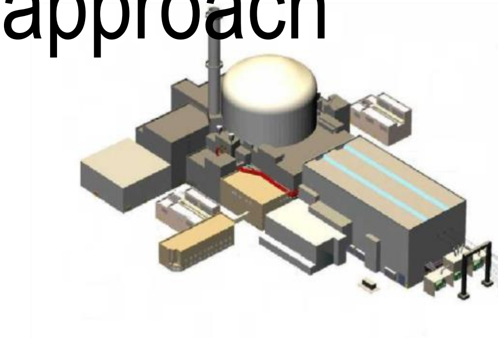


1 Focusing on Prevention, in a "Defense in Depth" approach, and reducing the probability of accident

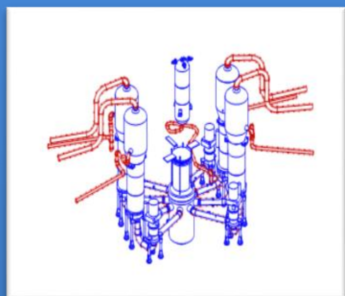
2 Taking into account, as a postulate, from the beginning, the possibility of a severe accident

3 Increased robustness versus internal & external hazards (fire, earthquake, flooding, aircraft crashes, …)

EPR safety goals: a multi-facetted approach



Improved reliability



Enhanced safety features

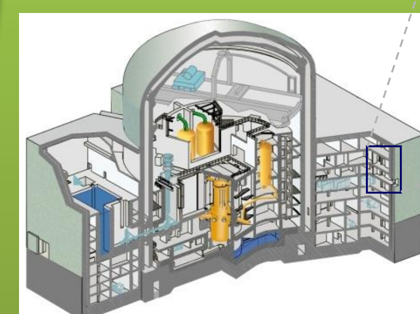
4 physically separate emergency systems each able of perfoming 100% safety function

Severe accidents included in design

Corium catcher & cooler In case of accident

Increased robustness for external hazards

Extended concrete shell



UPDATE IN RELATION TO LESSONS LEARNED FROM TEPCO FUKUSHIMA DAI-ICHI ACCIDENT

Report WENRA Safety Reference Levels for Existing Reactors

UPDATE IN RELATION TO LESSONS LEARNED FROM TEPCO FUKUSHIMA DAI-ICHI ACCIDENT

01 Safety Policy
02 Operating Organisation
03 Management System
04 Training and Authorization of NPP Staff (Jobs with Safety Importance)
05 Design Basis Envelope for Existing Reactors
06 Design Extension of Existing Reactors
07 Safety Classification of Structures, Systems and Components
08 Operational Limits and Conditions (OLCs)
09 Ageing Management
10 System for Investigation of Events and Operational Experience Feedback
11 Maintenance, In-Service Inspection and Functional Testing
12 Emergency Operating Procedures and Severe Accident Management Guidelines
13 Contents and Updating of Safety Analysis Report (SAR)
14 Probabilistic Safety Analysis (PSA)
15 Periodic Safety Review (PSR)
16 Plant Modifications
17 On-site Emergency Preparedness
18 Protection against Internal Fires
19 Natural Hazards

Requirements expressed by ASN

In its report ASN assesses the level of the French nuclear plants as sufficient

However, ASN required further measures such as:

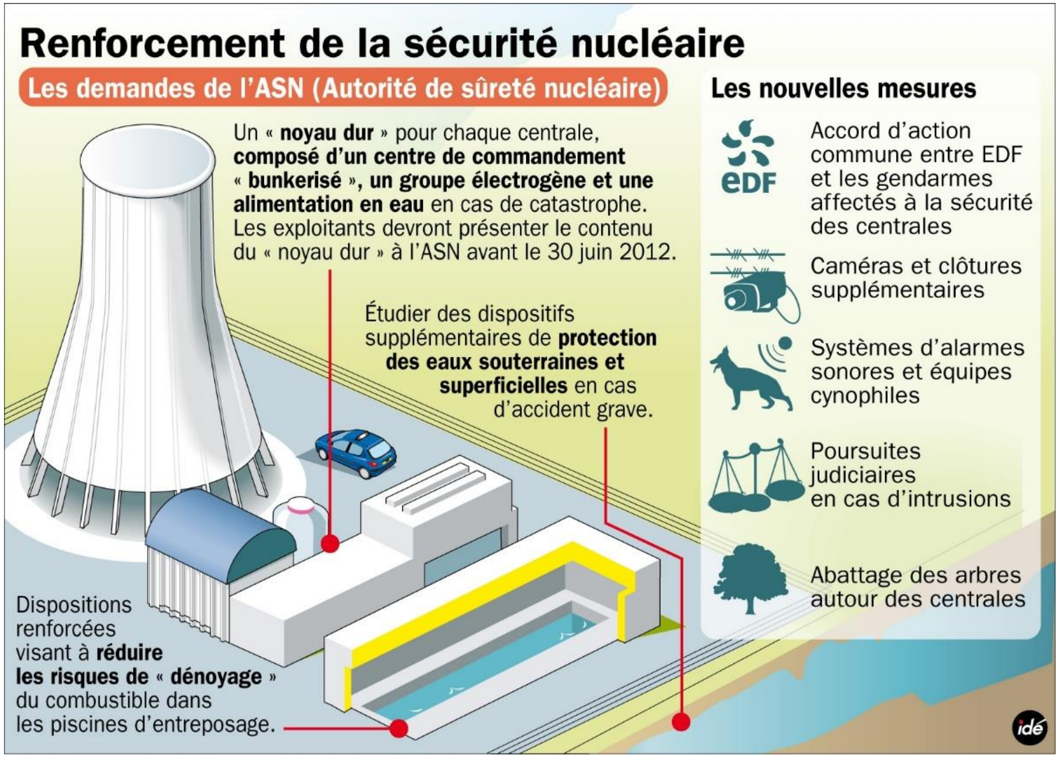
More diesel generators at each reactor

Setting up a “hard core” at every plant in order to fully master the safety issues

Setting up fast-acting forces to relieve the teams at the accident sites

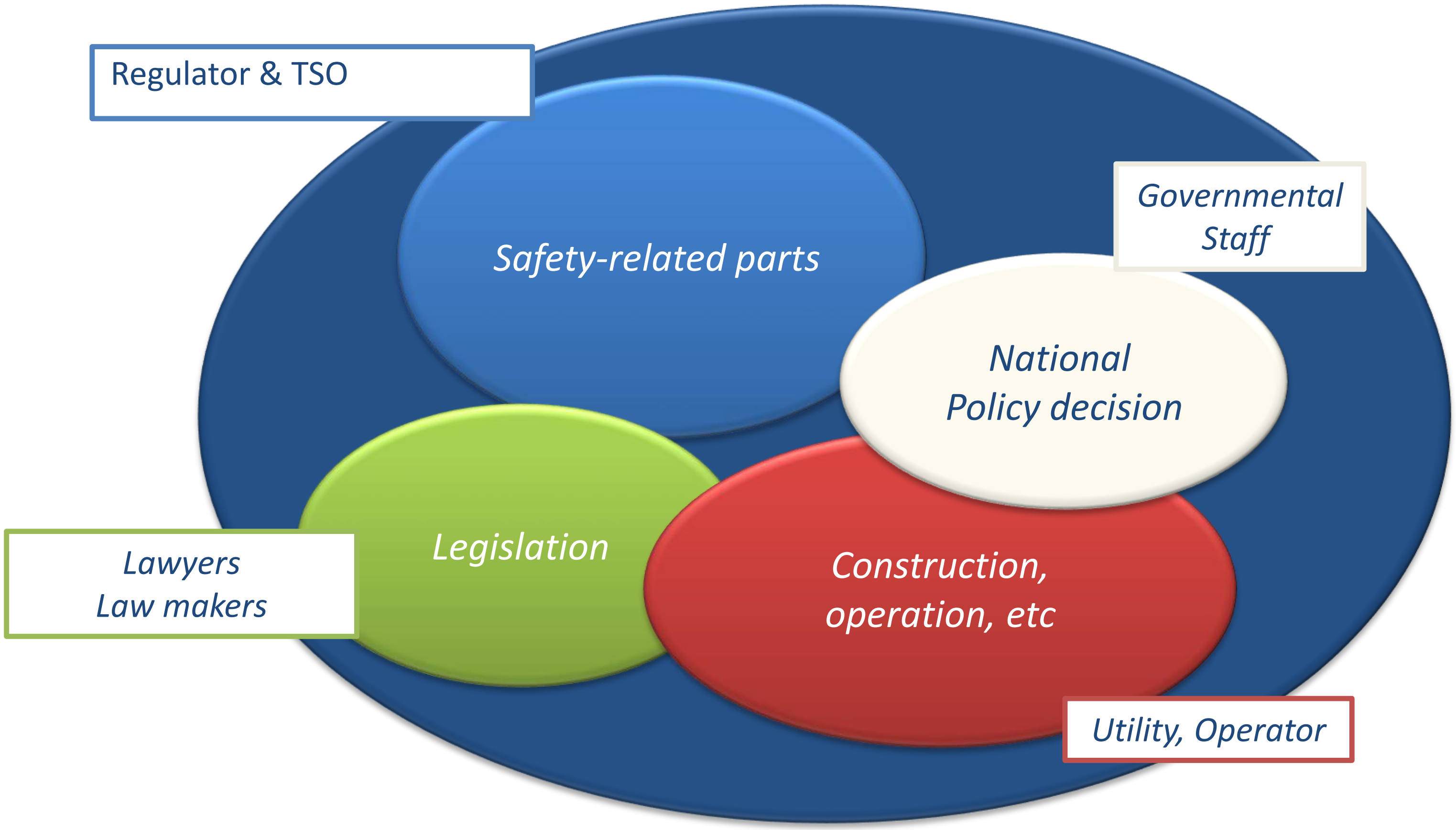
Increase the robustness of plants with regard to extreme situations (earthquakes, flooding,..)

Mitigate radioactive releases in case of accident



Allow the owner (utility) to fully ensure its management mission during a crisis

Human Resources for National Nuclear Power Programme



Nuclear Knowledge Management: Complex system

- It addresses many skills and competences at various levels
- Nuclear Knowledge is more than the sum of skills
- It is shared experience, attitude, preservation and transfer of knowledge over generations
- It must be addressed in a comprehensive manner and in a systemic approach
- It is strategic and requires significant investment (human and financial). It must be taken into account notably by Government
- However it is the Facility Owner/Operator who is the first responsible for safety thus including the quality of NKM

Nuclear Knowledge Management: Main Risks

At existing Nuclear Power Plants

Knowledge deficient decision-making, lacking the sufficient level and quality of knowledge and competence

New Projects

Because of possible time pressure, financial constraints, unavailability of needed skills
➔ risk of neglecting careful allocation of experienced human resources

New comers

Risk of underestimating the effort of establishing on time both domestically and with international assistance all needed human resources.

Education and training

Risk of failing to attract and recruit good students and to underestimate the quantitative and qualitative efforts in education and training.

CFEN: French Council for Education and training in Nuclear energy

CFEN created by the Minister of High Education and Research in 2008

- Assess the adequacy between the education offer, the students population in different curricula and the industrial/research needs with emphasis on safety
- Advise the Office of High Education on opening new academic curricula in the nuclear domain.
- Inform students of various curricula and possible professional careers and opportunities in nuclear power technology.
- Promote French international curricula.

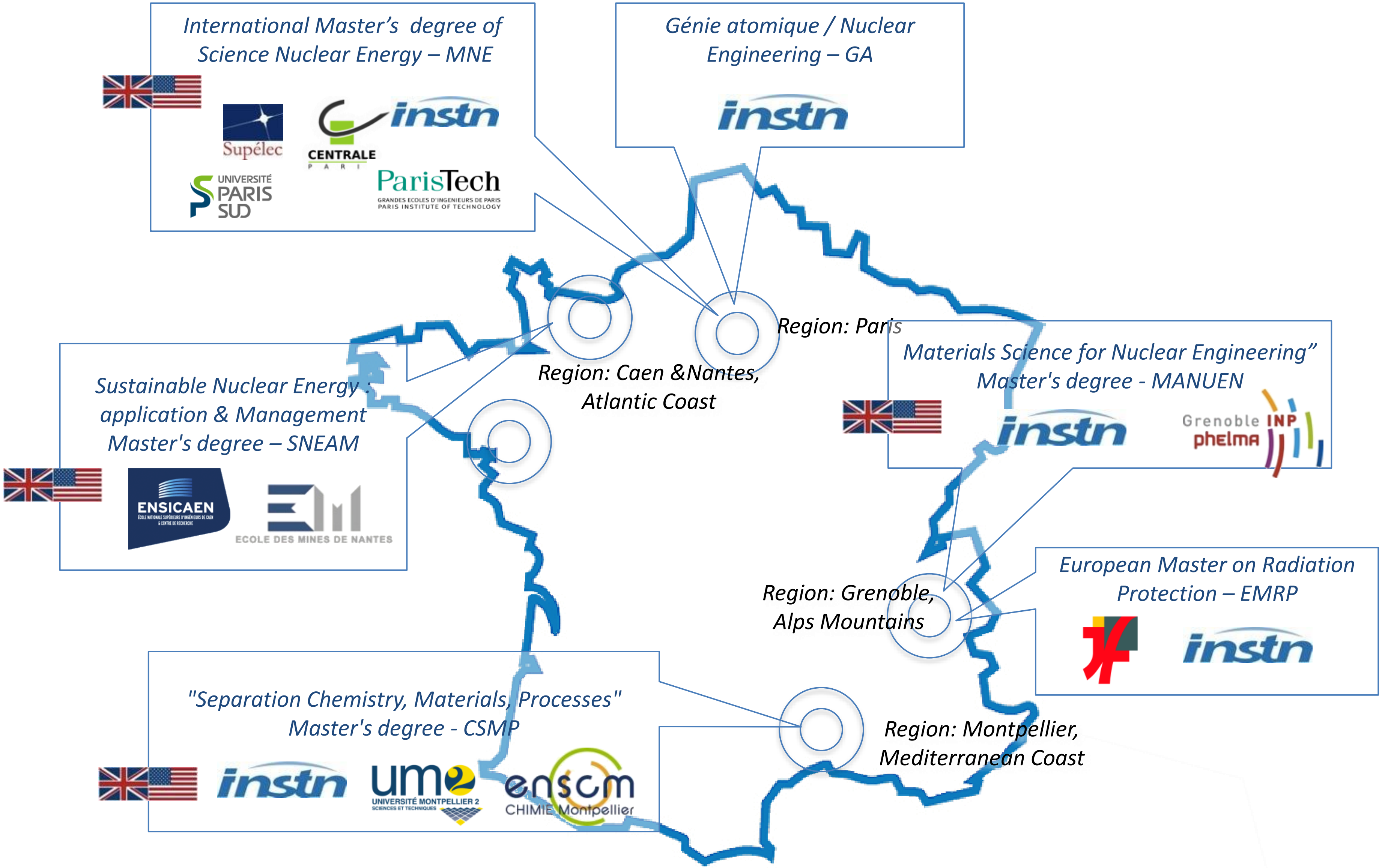
CFEN

Chaired by the High Commissioner for Atomic Energy

Members are:

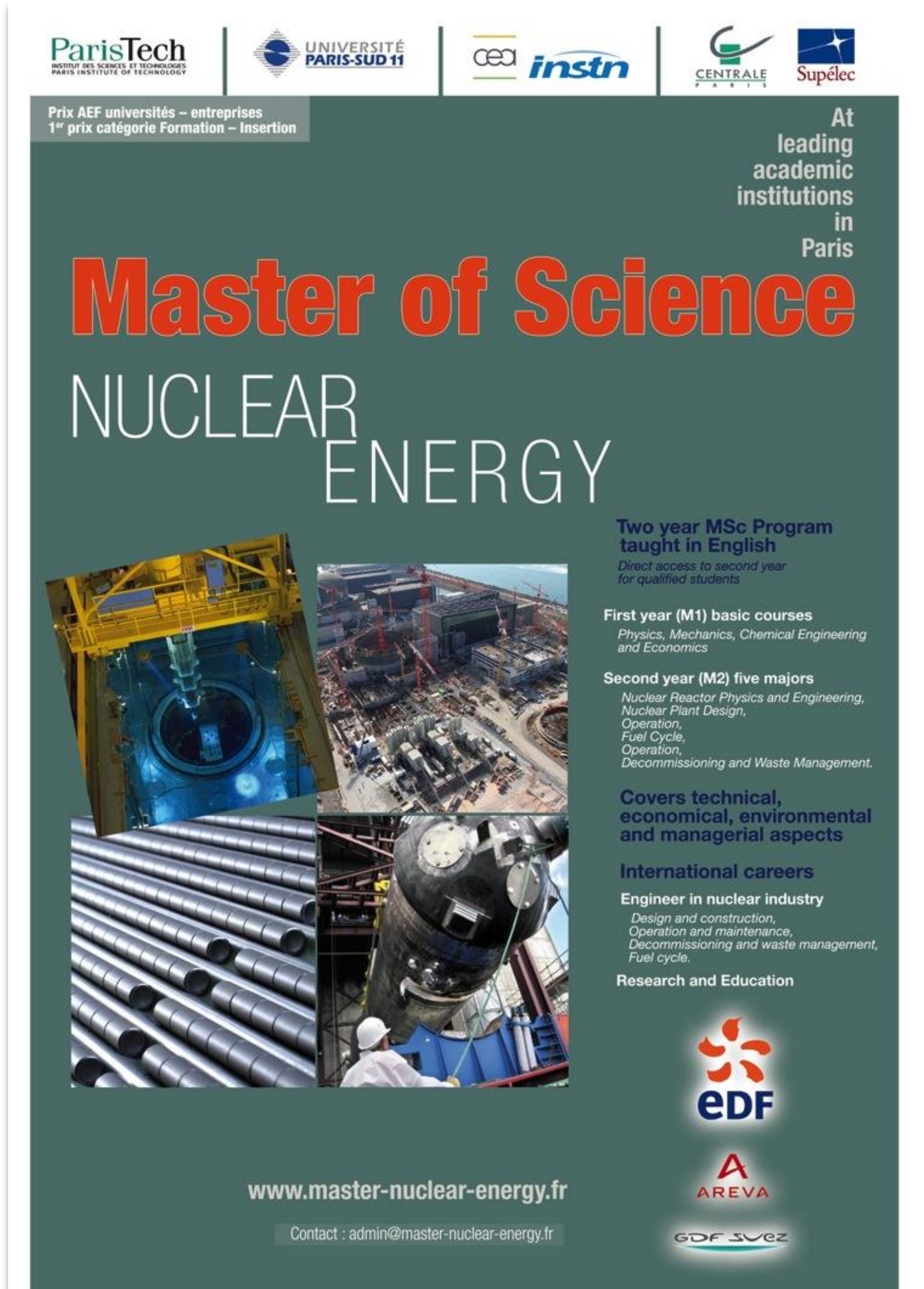
- representatives of governmental authorities in Education, Research and Industry,
- representatives of academic institutions (universities and engineering schools),
- representatives of the main industrials actors (AREVA, EDF, GDF-SUEZ, sub-contractors),
- representatives of main nuclear R&D institutions (CEA, IRSN, ANDRA)

Main Courses : 5 Master’s degrees & 1 Engineer degree



Master of Science in Nuclear Energy (MNE)

[*www.master-nuclear-energy.fr*](http://www.master-nuclear-energy.fr)



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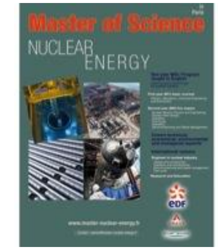
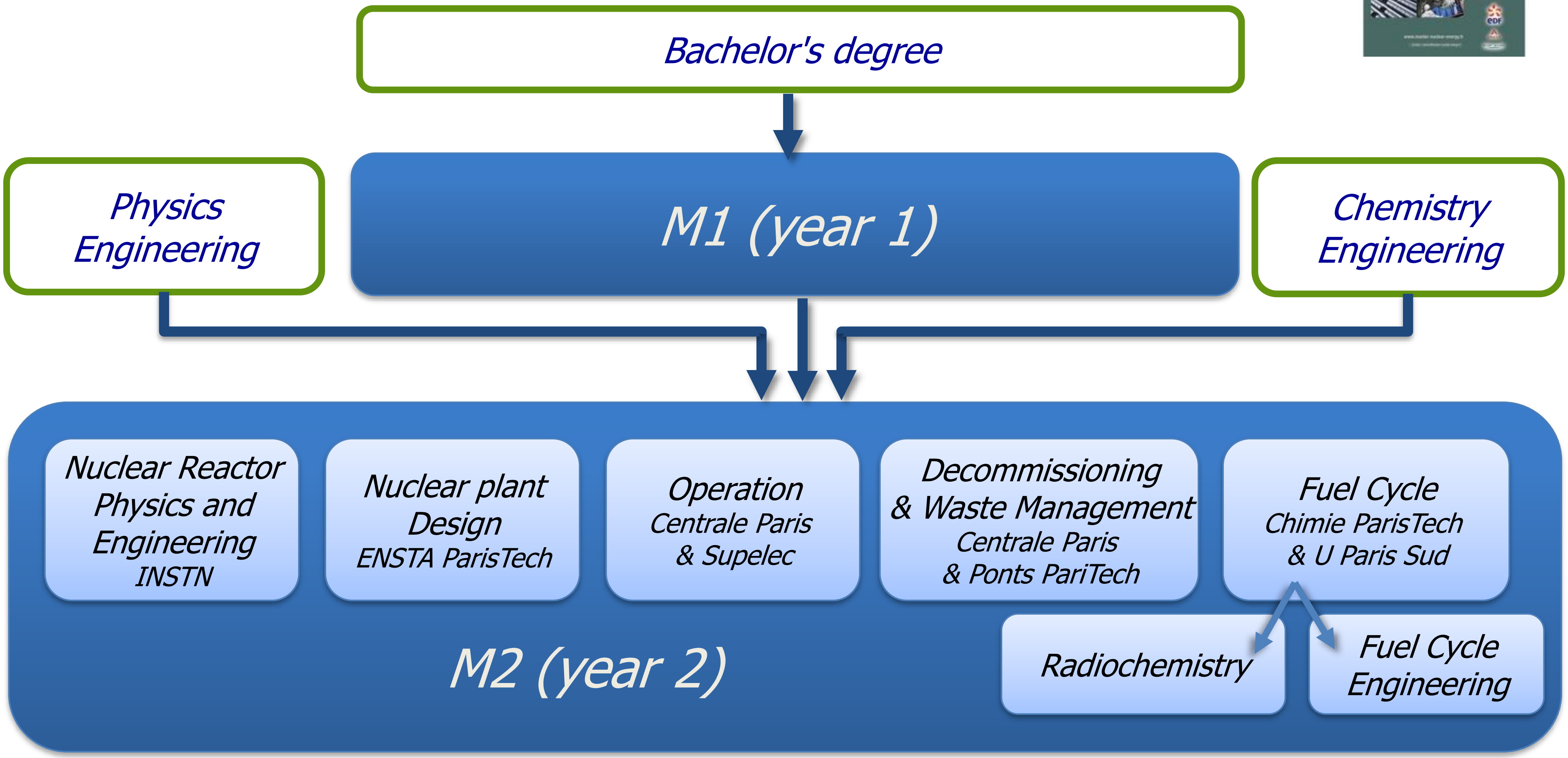
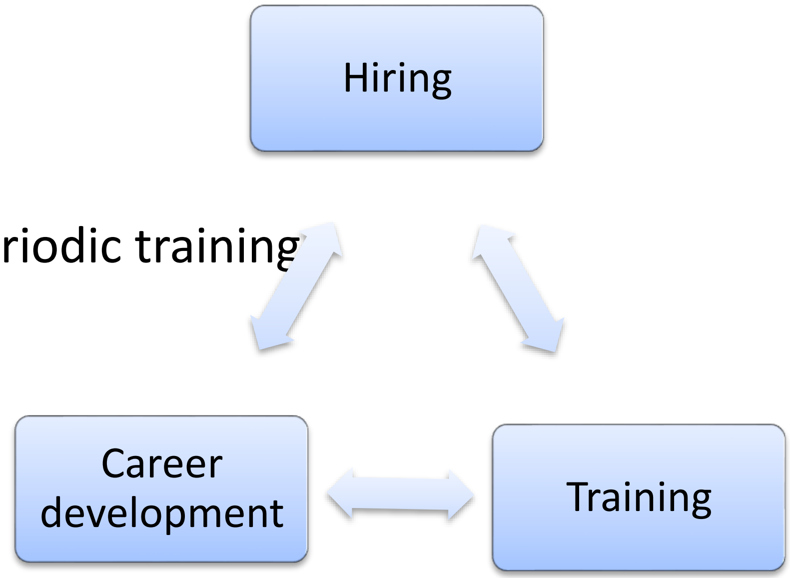




All courses in English. 100+ highly selected students

After recruitment by: Utility, Designer, Vendor, Supplier, Nuclear Regulator, TSO, ..

- Initial training and integration
- Operator’s training : initial qualification, periodic training
- Continuous vocational training
- Specialized training



Maintain a Strong Nuclear Culture with Safety at the core

Preserve and Enrich Nuclear Knowledge

In-House Training at EDF

EDF developped a comprehensive organization and program

- ✓ Progressively, over time, along with the development of NPPs
- ✓ Mostly based on internal means

A large organization

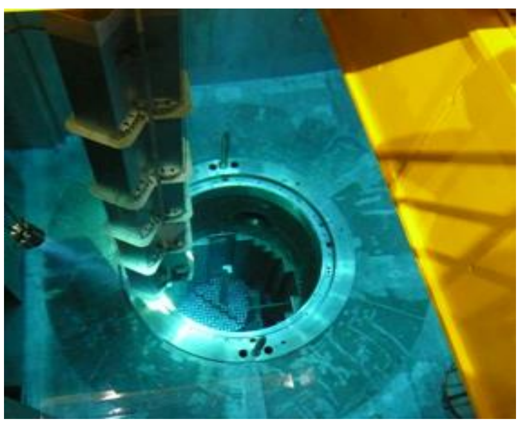
- ✓ ~ 3 M hours of training /year (large fraction for incoming staff)
- ✓ ~ 650 different courses
- ✓ ~ 740 persons, including ~ 530 teachers
- ✓ based mainly on 19 training centers, with full scope simulators, located at each NPP site

A significant commitment

- ~10% of total labor cost for nuclear sector

Many pedagogical tools

▲ CP0 Full scope Simulator



▲CETIC - Mock-up
for fuel loading/unloading

▲ Diesels training facilities

▼ Valves training

▲
◀training equipment
for hydro sector

Thanks for your attention