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EDF experience feedback

from Fukushima accident

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EDF at a Glance

37,7 million
customers worldwide (2011)

156,168
employees worldwide (2011)

€65,3 billion
of sales (2011)

628,2 TWh
of energy generated worldwide (2011)

99,6 g (EDF Group)
of CO_2 per kWh generated (2011)

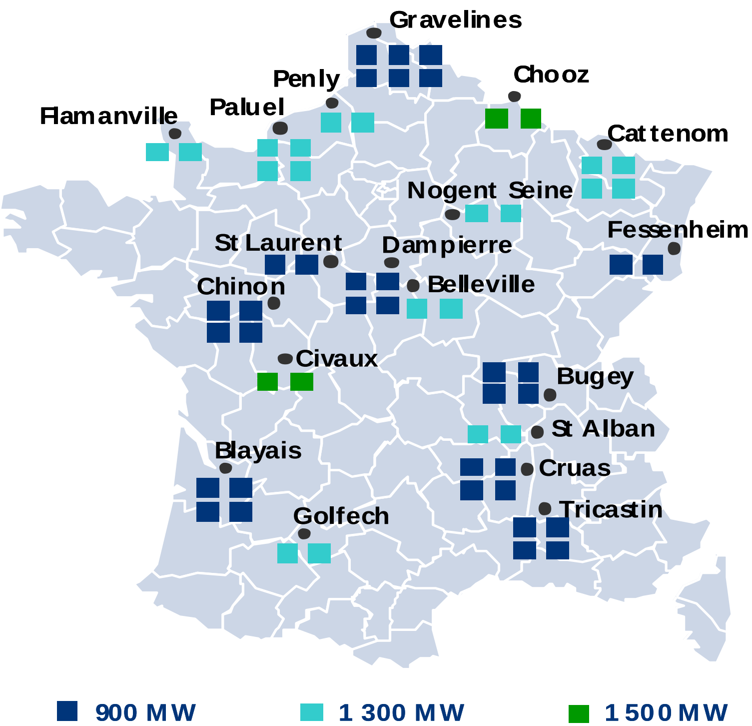
30,4 g (EDF in France)
of CO_2 per kWh generated (2011)

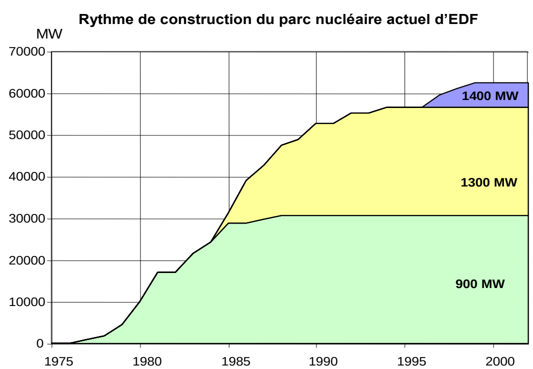
- **Net generation capacity worldwide: total 134,6 GWe => 628,2 TWh**
  Nuclear 74,8 GWe; Fossil: 34,4 GWe; Hydro & renewable: 25,4 GWe

  EDF Production in France: total 97,4 GWe => 459,7 TWhe
  85% of French electricity production (541,9 TWhe)
  Nuclear: 63,13 GWe => 421,1 TWhe (91,6%) ; Fossil: 14,27 GWe => 11,8 TWh e(2,6%); Hydro: 20 GWe => 26,8 TWhe (5,8%)

- Electricity: covering the entire chain, from engineering, generation to transmission, distribution and supply.
- Solidly anchored in Europe and its main countries such as France, Italy, Poland, and UK.
- Industrial operations in Asia, Brazil and the United States
- Natural gas: a major player (France:18 TWh; Italy 40 TWh; UK: 26 TWh; Belgium 16 TWh)

EDF Nuclear facilities in France





58 Pressurized Water Reactors (PWR)
on 19 sites: 63 GW

Three standardized series:
=> a major safety and economic benefit
- 900 MW: 34 units, 31 GW
- 1300 MW: 20 units, 26 GW
- 1500 MW (N4): 4 units, 6 GW

Experience as architect engineer / constructor and operator of the French nuclear fleet unique in the world
- safety and transparency as a major priority
- average operation time: 26 years (10 to 34 years)
- Experience feedback: ~ 1500 reactor years
- Periodic 10 years Safety Reassessment process

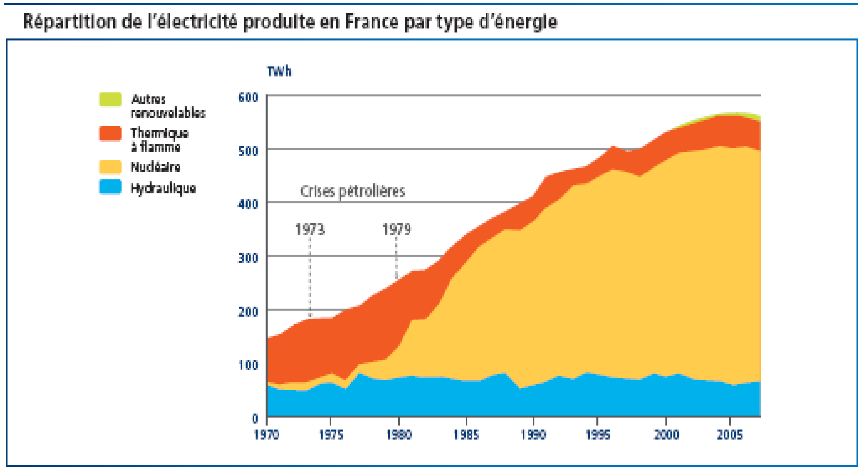
==> Long term operation: goal up to 60 years

EPR under construction: Flamanville 3,
Prospect for Penly 3

Decommissioning program: 9 reactors
(6 GGR, HWGCR Brennilis, SFR Creys Malville SFR, PWR Chooz A)

EDF Nuclear Generation Fleet in Europe

- **EDF nuclear generation (2011):**
  => 421,1 TWh (+3,2%)
  Nuclear capacity 63,13 GW

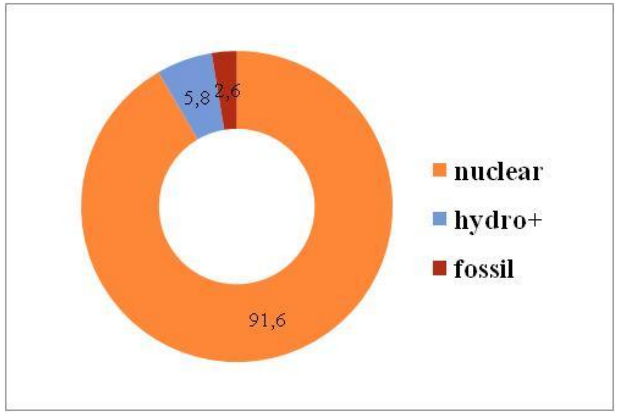


Source : RTE.

- **A highly competitive generation mix**

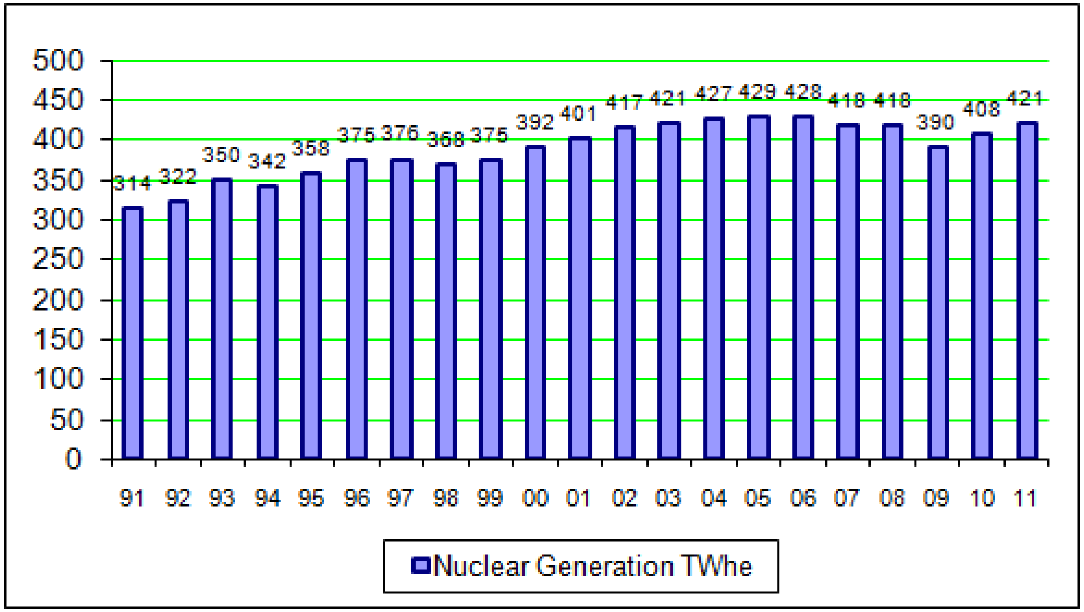
EDF Production in France: 97,4 GWe => 459,7 TWh
Nuclear: 63,13 GWe => 421,1 TWh (91,6%) ;
Fossil: 14,27 GWe => 11,8 TWh (2,6%);
Hydro: 20,00 GWe => 26,8 TWh (5,8%)

- **A clean low carbon energy mix, 95% CO2 free**
  Nuclear: ≈ 4 g/kwh;
  EDF France ≈ 30,4 g/kWh;
  EU average: 337,3 g/kwh



- **EDF Energy (UK)**
  8.7 GW nuclear (14 AGR, 1 PWR) => **55,8 TWh** (+ 15,5%)

Production performance :
Improving the fleet availability remains a priority



Nuclear generation :
421,1 TWh in 2011 (+ 3,2%)
- Load factor Kp: 76,1 % (= kd x ku);
- Availability factor Kd: 80,7 %;
- Utilization factor Ku: 94,3 % (frequency control, load following…)
- Use of MOX fuel on 22 units

Top 10 units:
availability factor kd : 89% to 98 %

Fortuitous unavailability: 2,2%

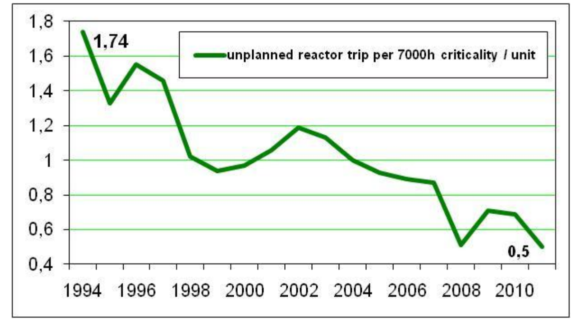
- Middle term goal: improving technical performance to reach 85% adapted to french energy mix specificities (mix of cycle length: 12 and 18 months basis), ten-years visits

- Main recent technical issues:
  - Steam Generators cleaning and replacement program (done on 21 units)
  - generator stators , main transformers …
  - maintenance, outage management

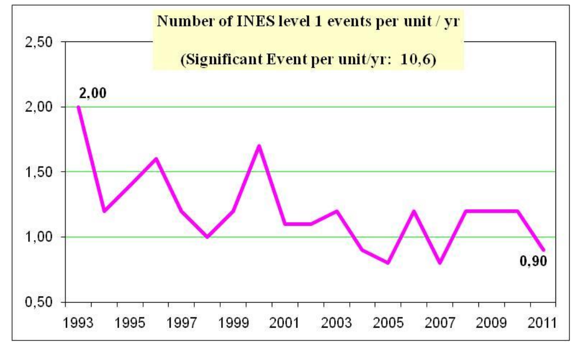
- Impact of ten-years visits (90 days outages): 9 in 2011 (5 in 2010), impact on kd : 1,5%

Safety: a priority at all levels

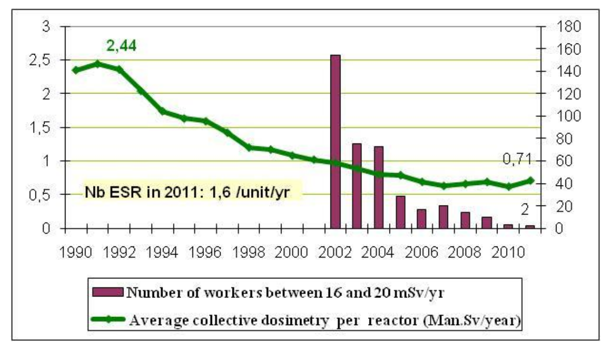
- **Safety indicators** (/ unit / year):
  unplanned automatic trip : ≈ 0,5 (0 on 38 units)
  events reported to ASN: ≈ 9 level 0 and ≈ 1 level 1
  level 2: - clogging of water intake at Cruas 4 (2009)
  - diesel generators at Tricastin (wear of internal pieces) (2011)



- **Radiological protection:**
  ALARA progress, average collective dosimetry: 0,7 Man-Sv /unit/yr



- **Internal independent control structures:**
  => General Inspectorate for Nuclear Safety at EDF Presidency
  => Nuclear Inspectorate at Nuclear Generation Division
  => Safety Quality Mission at each plant



- **International assessments and peer reviews**:
  IAEA Osart (1/yr), **WANO peer reviews** (2 to 3 /yr)

- **International controls** (Euratom)**:** safeguards, material accounting…

==> Under the control of Nuclear Safety Authority (ASN)
(June 13, 2006 Act on nuclear safety and transparency)

EDF strategy for sustainable nuclear generation Key Progress and Challenges

Remain a reference for the nuclear industry worldwide

- Nuclear safety and safety culture as a first priority at all levels
- Experience feedback and efficiency of defense in depth, emergency preparedness,
- post FKH experience feedback: Complementary Safety Assessment, Fast Action Force...
- Competitiveness, availability and operational performances ; studies on power uprate ...

Plant Long Term Operation management

- Periodical 10 years Safety Reassessment: goal up to 60 years

Fuel cycle efficiency, reprocessing / recycling and HLW waste management

- A major asset for sustainable nuclear energy

Succeed in the EPR Flamanville-3 construction project, while drawing experience feedback

- public debate and acceptance
- safety, quality, schedule, cost, etc.

Being a major player in the international development of Nuclear Power

- international cooperation
- New Nuclear Build projects: China (2 EPR), UK (EPR GDA), USA (licensing of US EPR), Poland, RSA
- studies on development of a 1000 MW GEN3 reactor

Developing the skills and competences needed to achieve these objectives

- International Master in Nuclear Energy

Operation time extension for Nuclear fleet: Safety reassessment, modernization and updating

Every 10 years, a safety reassessment process is performed for each standardized NPPs series

- reassessment of the licensing basis, experience feedback, **new knowledge or evolutions**,
- internal/external event: earthquake, flooding, electrical supplies, cooling water, industrial environment...
- severe accidents prevention and limitation of consequences
- probabilistic studies, backfitting (cost / benefit analysis),
- compliance assessment and checking , ageing assessment, R&D

=> as a result, a new safety basis and an improvement programme is proposed to ASN

An on going process: preparation, strategic decision, engineering studies, implementation

- 900 MW: first VD3 at Tricastin 1 and FSH 1: ASN agreement to proceed beyond up to 40 years
- 1300 MW: VD3 in preparation (FOAK in 2015)…
- encompassing post Fukushima Complementary Safety Assessment

A 40 years operation time can be technically attained for existing plants

- implementation of systematic maintenance program and periodical safety updating of the units;
- sustained R&D focused on long-term behaviour of main components and aging ability,
- creation of Material Ageing Institute at EDF R&D, with major utilities, CEA and research laboratories

EDF objective: operation time up to 60 years for the whole nuclear fleet, under ASN control

- pursuing the continous safety level and environment protection improvement program;
- anticipation program for aging effects or obsolescence of components

The EPR construction Project

A "robust and evolutionary" design Benefiting from extensive experience feedback

Building in progress at Flamanville 3

Studies for Penly 3

Launching of a 2nd EPR at Penly (in partnership) to comfort security of supply in France and Europe in the years to come

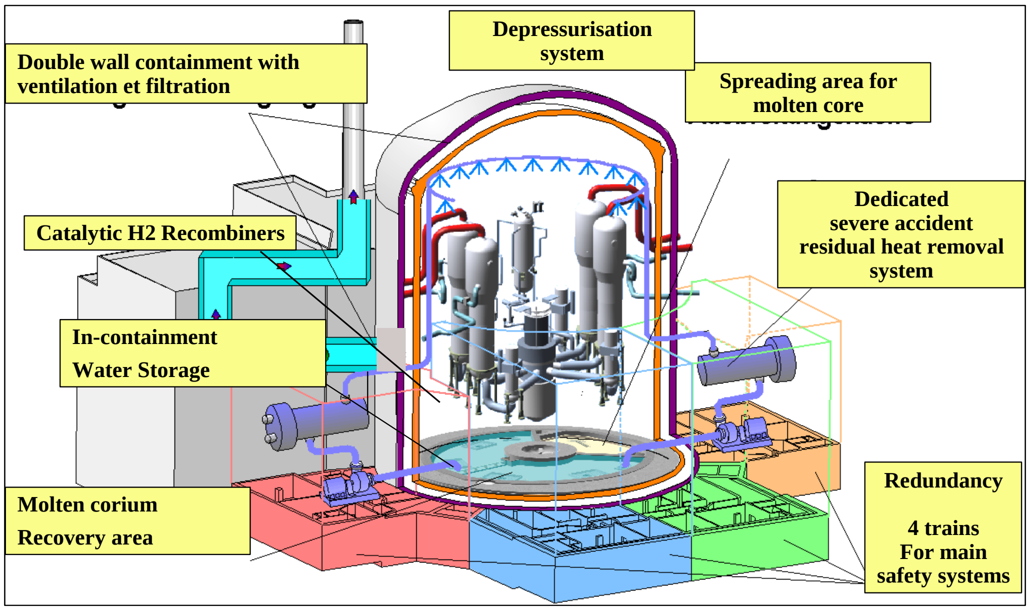
Public debate has been completed in 2010

EPR : Building in Progress at Flamanville 3 and Taishan (China)

An evolutionary and proven design, embedding improvements resulting from experience feedback and French German cooperation over more than 10 years

- **Severe accident mitigation embedded into the design**
- **External aggression resistance (aircraft crash)**
- **On going safety analysis process with ASN:**
  e.g.: I&C , human machine interface ...

Main Safety Engineered systems



- Site selection: October 2004
- First concrete: end of 2007
- 98% contracted (end 2011);
- Civil work & Reactor building erection: 88%
- Electro-mechanical work : 20%
- construction duration: 100 months;
- Investment 6 bn Eu;
- Start of electric generation: 2016

=> Experience feedback for future EPR fleet
(Flamanville 3, Taishan 1/2 Chuna, OL3 Finland, Hinckley Point UK, Penly 3..)

Results of "Stress tests"

Complementary Safety Assessments

in EDF reactors

Post Fukushima action plan
The legal framework in France and EU

In the wake of the FUKUSHIMA NPPs accident, caused by a large tsunami, the French Prime Minister required ASN on March 23rd, 2011 to perform Complementary Safety Assessments (ECS) and to report end of 2011 on the status of each power plant **in five areas** : :

- Flooding
- Earthquake
- Loss of electrical power
- Loss of heat sink
- Severe accident management

The EU Commission also asked to perform « stress tests » in the European NPPs

- In FRANCE, ASN included all the European « stress tests » requirements in its own Complementary Safety Assessments requirements, hence ensuring full consistency with the EU Council requirements.

- In addition, it was asked to include an assessment on the principles and regulations of subcontracting in the NPPs

Post Fukushima action plan
EDF has submitted its reports to the ASN

The methodology has been defined by ASN, in a consistent way with EU requirements. 19 EDF reports (sites currently operating and those under construction) have been submitted to ASN on September 15, 2011 as required (7,000 pages - published on the ASN website: www.asn.fr)

- Following this work, EDF confirms the current good level of safety and adequate margins for all nuclear facilities.

- Most of the lessons learned were already anticipated as part of the periodical 10 year safety reassessment process, especially for flooding hazard.

- The new analyses led EDF to put forward to the ASN supplementary measures, taking potential situations even further than previous hypothesis

- These analyses will improve even more the good level of safety at EDF's NPPs
=> ASN has published its overall report with its own assessment and requests: end 2011
=> A benchmark has been launched at EU level (ENSREG)
=> A report is being prepared for IAEA CNS extraordinary meeting in August 2012

- EDF checked that the conditions for subcontracting activities are in compliance with its responsibility in terms of Safety and Radiation Protection

AUTORITÉ DE SÛRETÉ NUCLÉAIRE asn

eDF

French Safety Authority conclusions

- On January 3rd, 2012, the ASN presented the conclusions of its report concerning the Complementary Safety Assessments
- The current EDF NPPs operate with a satisfactory Nuclear Safety level.
- The present seismic margins of the EDF NPPs are adequate and satisfactory.
- The thorough reassessment performed on the sites after the flooding event in BLAYAIS NPP in 1999 lead on all NPPs to a high level of protection against flooding.
- The advanced and robust design of the EPR ensures upfront an improved protection in case of a severe accident.

The CSA : a two steps methodology

1

In-depth assessment of the current safety layers according to the current design basis of:

- Physical protections such as dikes, embankments, anchorage, water resources,…
- Design Basis accident management
- All relevant systems used for the safety demonstration

2

New analysis going beyond the current design basis referential :

- Efficiency of protections
- Consideration of extreme situations
- « Hard core » of systems and equipment enabling to avoid releases with significant long term consequences

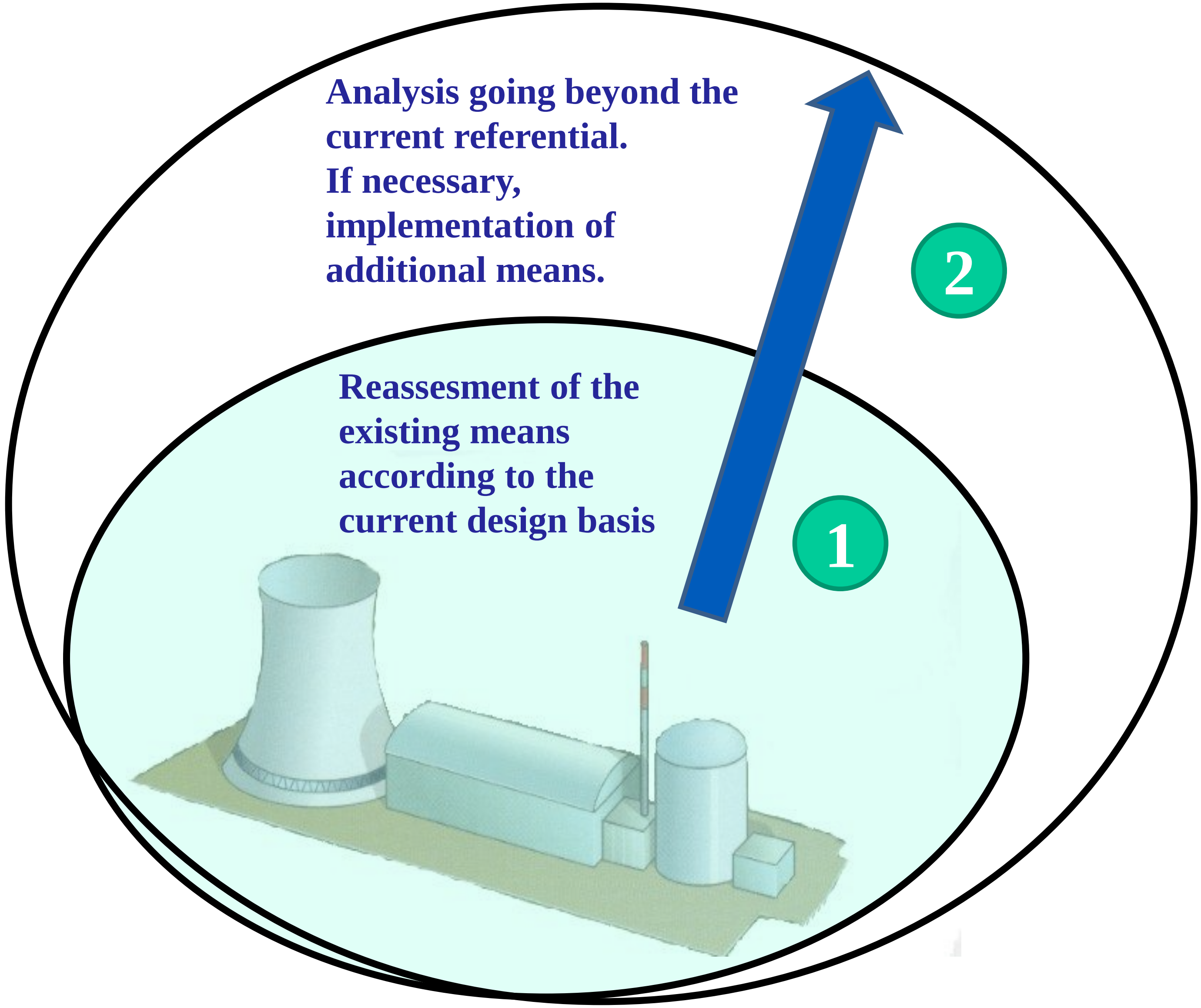
=> If necessary, implementation of supplementary means

- Equipment
- Human resources
- Local/national organization

The CSA : a two steps methodology

The areas to be assessed according to ASN requirements

- Earthquake
- Flooding
- Loss of heat sink
- Loss of electrical power
- Severe accident management



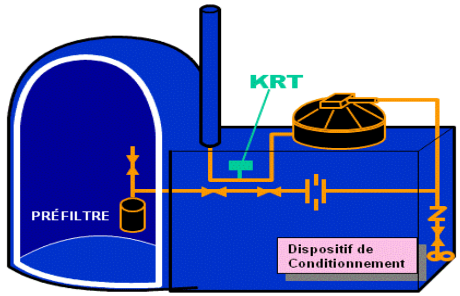
Improvements for existing NPPs following CSA

- **Enhancing robustness of systems designed to protect key safety functions against external hazards (earthquakes, flooding...)**

- flooding: protection of equipment and materials (dams or dykes, building leaktightness...)
- Supplementary protection of electrical switchyards against flooding
- robustness against seism: reinforcement of supports and anchorages, electrical equipment..

- **Increasing water make-up and electrical power supply capacity, to cool the reactor and avoid fuel uncovery** (reactor core, spent fuel pool)

- additional water reserve (basin, underground table…)
- reinforcement of the back up cooling water supply (tank...)
- implementation of one additional back up diesel generator on each unit: back up supply of AFW pumps, water make-up to RCS and spent fuel pool, thermal pump to supply water in RCS
- spent fuel pool operation: instrumentation (level, temperature), supply systems, fuel handling..



- **Protective measures in case of core meltdown, minimizing radioactive releases**

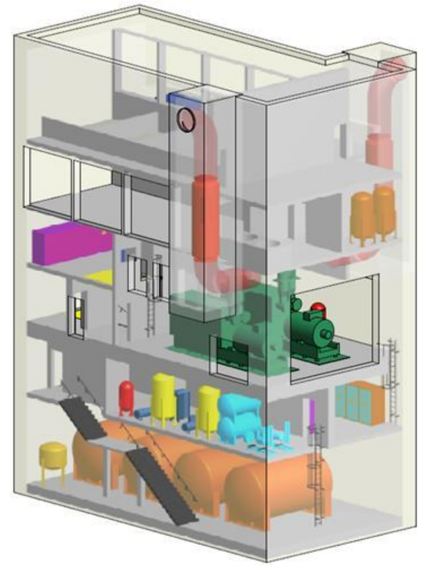
to avoid significant long-term contamination of surrounding areas

- robustness and efficiency of U5 containment filter to limit external releases (cesium...), seismic resistance, improvement of fitration capabilities (iodine),
- soda in reactor building sumps (to trap iodine)
- studies of countermeasures to avoid contamination of the water table (in case of basement melt through)

- **Reinforcing site and national emergency preparedness organizations:**

- personnel and equipment

Key additional measures



• Implementation of a "Hardened safety core" of systems, structures and components designed to prevent large radioactive releases to the environment in extreme conditions considered by ECS reviews.

- protected against extreme external hazards exceeding the scope of the current design basis.,

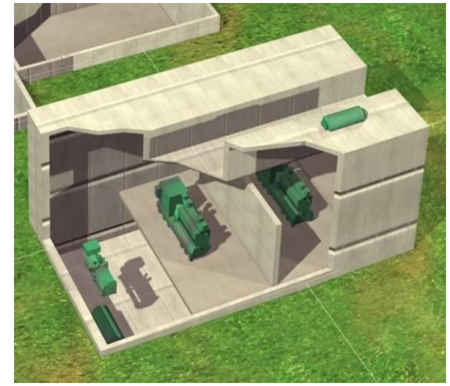
- to increase mitigation and robustness beyond design

• Nuclear Rapid Response Force (FARN)

- The setting up a supplementary "resilient" line of defense through a national "Rapid Action Force" (FARN) ready to support a site in trouble within 24h, and adequate Logistics,

- reinforcement of crisis management premises on site

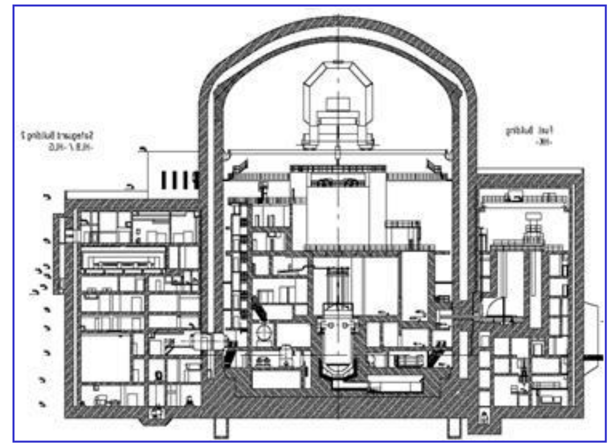
The EPR and CSA



Higher robustness by design :

4 separated 100% safety trains

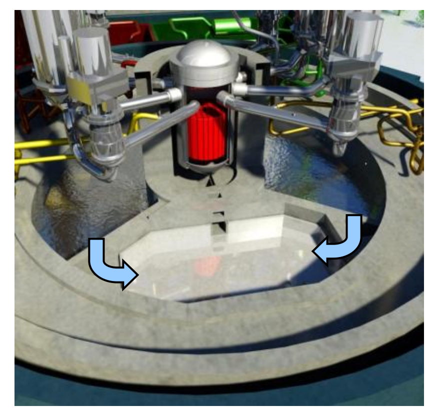
6 diesels : 4 main diesels + 2 emergency diesels, in two separated buildings



Large Emergency Feed water **reserves**,

Systems **Diversification** for sea water pumping,

Core-catcher and flooding of the corium avoiding basement melt through



Reactor Containment Building : high **pressure resistance,** double walled with steel liner

Control and limitation of Containment building pressure using an ultimate safeguard cooling system.

The EPR and CSA

The Complementary Safety Assessment requires to assess all situations where every emergency mean has been lost

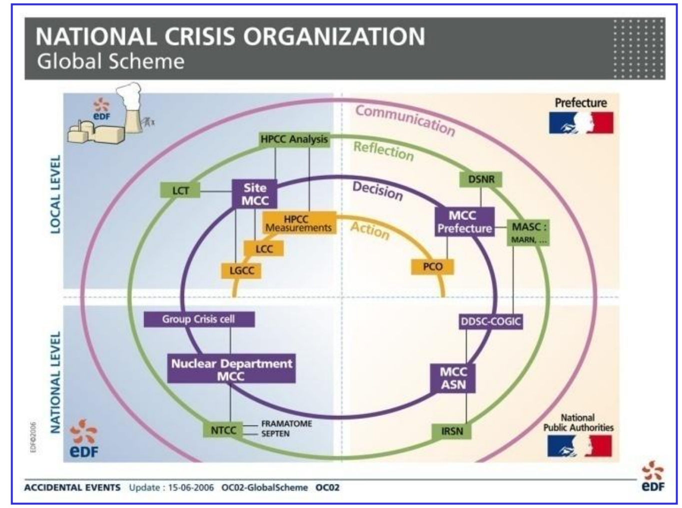
The proposed additional countermeasures :

- Increase the robustness of the present existing emergency diesels,

- For FLA3 & PEN3, use the existing water reservoirs located on the top of the Normandy cliffs and connect them on the systems designed for the residual heat removal,

- Add a mobile water supply means for the ultimate containment building cooling system.

Reinforce the Emergency Crisis Organization and emergency means on site



- **Reinforcement of the skills present on site,**

- **Optimization of the organization and procedures :**
  - Training and seminars,
  - Reinforcement of operability and reliability of emergency equipment,

- **Nuclear Rapid Response Force (FARN)**

- **Local Emergency means – Regional and National Emergency means,**

- **Electricity and water connections (plug & play)**

- **Emergency Crisis Center on site :**
  - More robust local crisis management,
  - able to deal with a whole site emergency (multi-units)

Nuclear Rapid-Response Force

Objectives: **to re-establish and/or maintain reactor cooling with the aim of avoiding any core fusion or any significant release**

Missions:

Intervene
- **Intervention within 24 hours** (1 corporate and 4 regional dedicated teams…), in support of shift teams

Evaluate
- Situation of site
- Positioning of rear base (10 to 30 km)

Act
- **Reinject water into the installation**
- **Plug & play connections (power, pumps…)**
- **take up of operation after 24 h**

Deploy
- **Large scale equipment (3-4 days)**
  - Protection, Intervention, Control
  - logistics

Prepare
- Actions to remain in effect, after the first days of autonomous action
- **Management throughout the entire duration of the situation (water provision, effluent processing, awste etc.)**

FARN: OBJECTIVES, ASSUMPTIONS & FEATURES

FARN objectives

Intervene in the areas of **operation**, **maintenance** and **logistics service** on an site where **an accident occurred** in order to **restore electricity and water supplies within 24 hours** :
- to limit the degradation of the situation
- to confine liquid and/or solid radwaste (for instance re-inject liquid waste into the reactor building)
- and where possible, to avoid core meltdown, first in assistance and then taking over from the shift teams which have been implementing the first emergency actions on site.

Assumptions for FARN

- **Only one site out in accident condition** (the largest...)
- Important **destruction** of the infrastructures (including access to the site)
- **On-call teams potentially unavailable**
- **Possibility of cumulative risks** (radiological and/or chemical)
- FARN mobilization by corporate decision upon Site Manager's request
- Site Manager remains the nuclear operator
- FARN's actions are performed within the frame of the National Emergency Crisis organization

Main features of FARN's intervention

- **Liaison** with the national Crisis Center and the Site Management
- Dedicated **EDF** staff (multi-skilled people...)
- FARN personnel actions **fully comply with the occupational safety and radioprotection rules** which have been defined for such a situation
- 2 stages organization: i) Reconnaissance & short term and ii) mid & long term)
- able to work in **autonomy** during several days on a site which has been partially damaged.

Fukushima demonstrated the importance of a Strong Owner / Operator

A nuclear program is not only the selection of the nuclear vendor and construction.

The ability to efficiently manage, during all the plant life:
- Normal, Incidental and Accidental situations;
- Periodic Safety Reviews and Long Term Operation phase (60 years..)
is of upmost importance for all stakeholders…

It makes **EDF's firm convictions** valid in that :
running a nuclear power plant safely and efficiently is enhanced when the operator :
- **has also been involved in the design and the building of the plant,**
- **and remains continuously involved in engineering and design issues through experience feedback and periodic safety reassessment process.**

- In the post-Fukushima context, Banks and investors value all the more the quality and the track-record of the owner operator which is a key condition for the financing of new nuclear projects.

Fukushima impact on New Nuclear Build

- It demonstrated that the plant owner/operator is on the frontline for warranting nuclear safety,

- The strengthening of safety requirements (WENRA safety objectives, MDEP...):
=> Generation III and III+ reactors are now the reference;
=> In Europe: the WENRA safety objectives for new reactors
=> Safety is the first priority which, nonetheless, does not prevent the nuclear power project from being competitive.
=> It also emphasizes the case for strengthening and harmonizing safety requirements (WENRA safety objectives, MDEP...), so as to facilitates the development of standardized designs with enhanced experience feedback

- The independence of the regulator (from the licensee or any other body...) is a key factor for the credibility of a project.

- International institutions' greater role (IAEA, OECD/NEA etc.) in the development of new nuclear power programs forwarding high safety standards
and the role of WANO to enhance operator's responsibilities at international level.

Thank you

for your attention

and your questions …