EDF LTO Approach

TECHNICAL AND REGULATORY ISSUES FACING NUCLEAR POWER PLANTS

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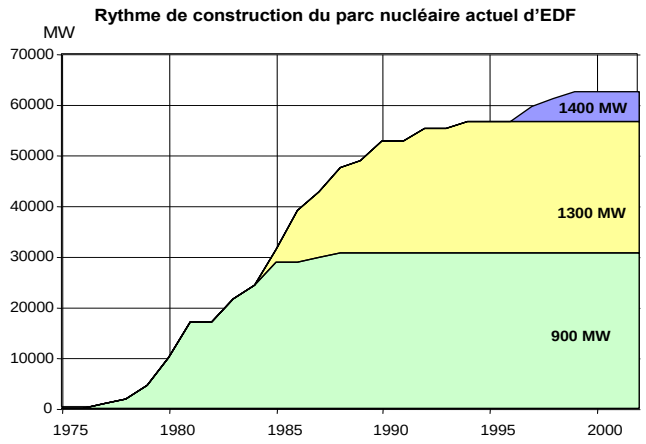
DIPNN – DTI

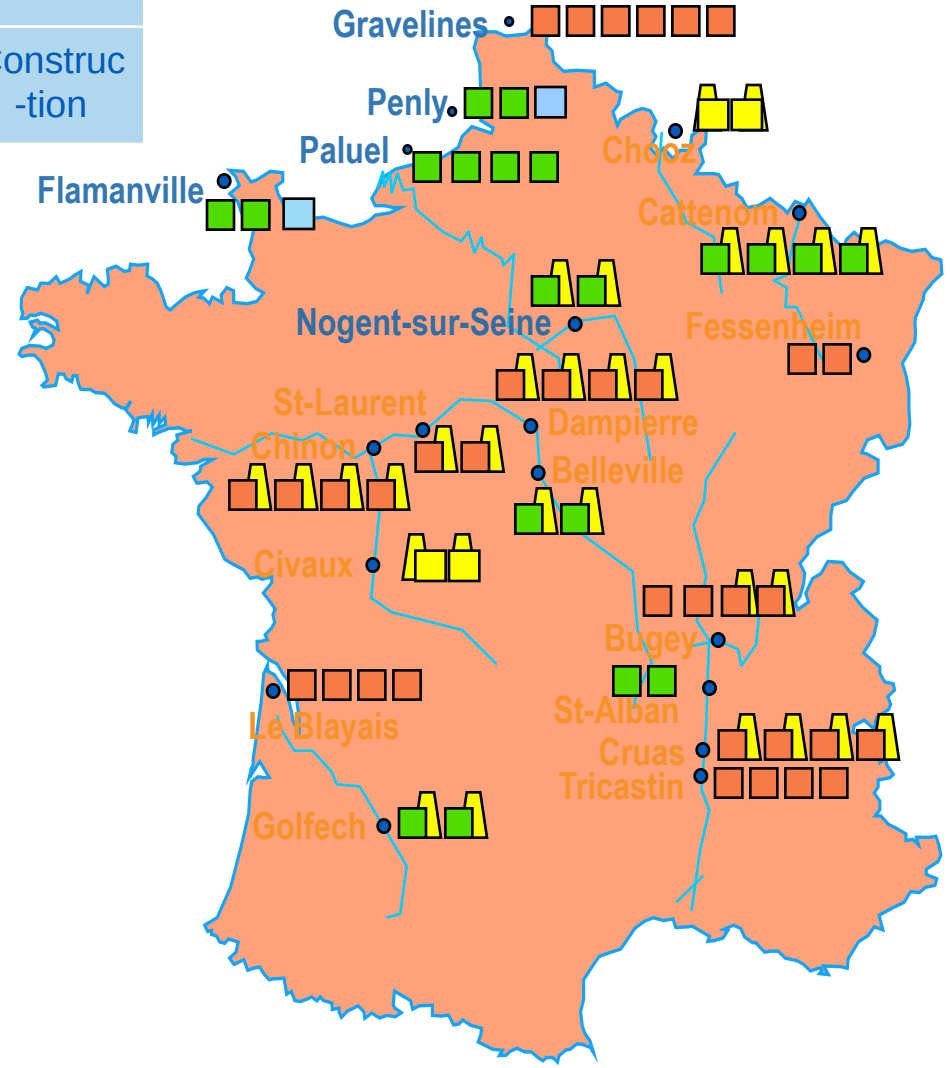
1. **EDF PWR Fleet data**
2. **LTO context**
3. **Overview on Material Ageing R&D Program**
4. **Conclusion**

EDF PWR fleet

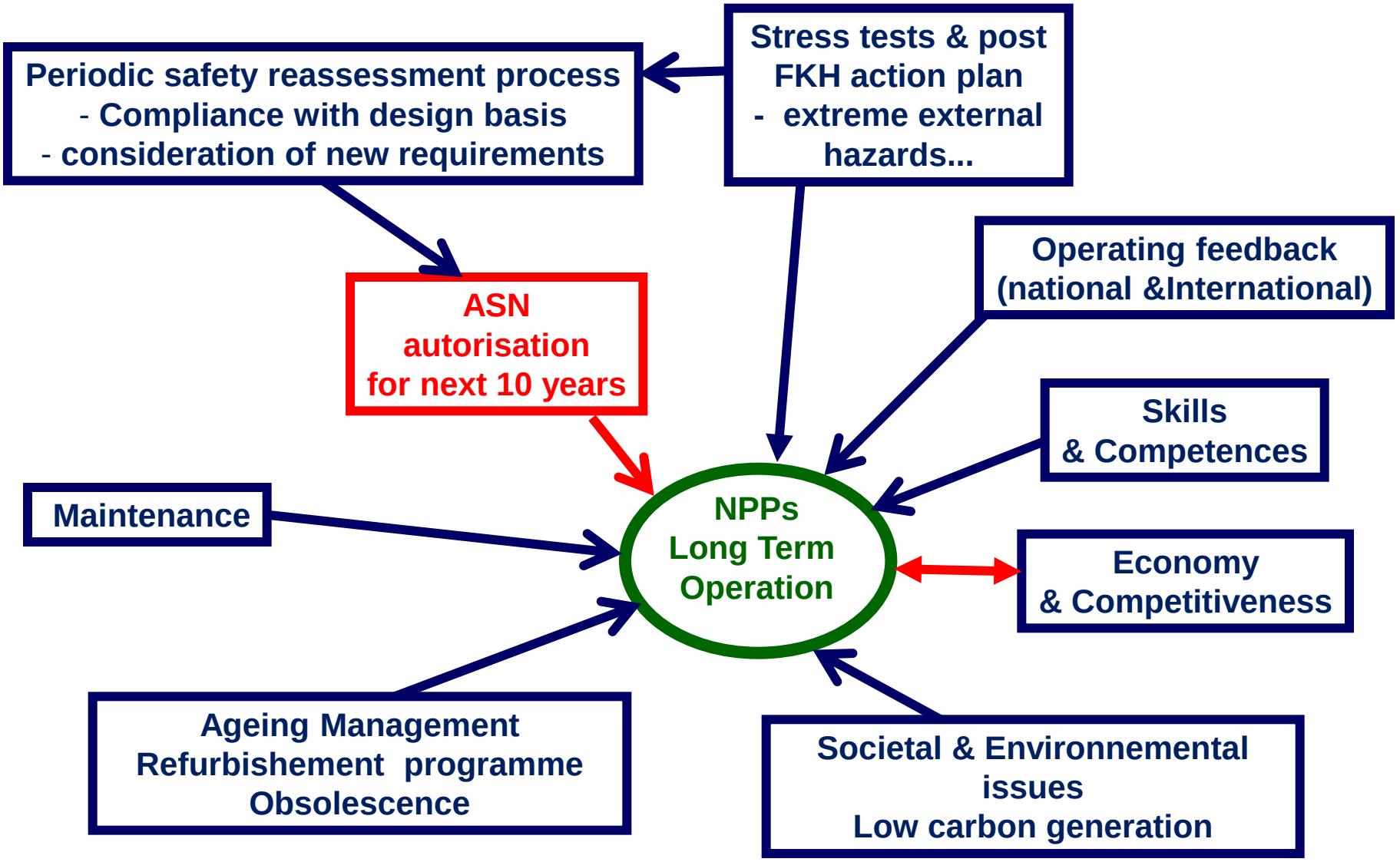
NPP series	900 (3 loops)	1300 (4 loops)	1450 (4 loops)	1650 (4 loops)
Number	34	20	4	1
Average age	34	28	18	Construc -tion

- 58 reactors in operation
- 1 reactor (EPR) under construction
- spread out over 19 sites
- Average age : 29 years
- 18 units will reach 40 years before 2020





Long Term Operation: a multi facets challenge



The Periodic Safety Review (PSR) process

- A mandatory process
  - Implemented since the 2nd 10-year outage of 900 MW series
  - Introduced in the French law (TSN) in 2006
  - Common EU practice included in Nuclear Safety Directive
  - To be performed each 10 years
- It includes two main aspects :
  - Compliance assessment with existing safety basis, checking and inspections, assessment of ageing mechanisms, including
    - Basic inspection programs and additional inspection programs
    - Containment test, Main primary circuit hydro test
  - Reassessment and updating of the licensing basis (internal/external events, severe accidents, PSA...), taking into account experience feedback, new knowledge, best international practices & requirements applicable to new NPPs
- Enables to define measures to improve the safety of the plant
  - In practice these measures are implemented during the next 10-year outage (VD in French), which are longer than refueling outages

The Periodic Safety Review (PSR) process

French ASN allows 10 years operation after each PSR:

	VD1 (10 years)	VD2 (20 years)	VD3 (30 years)	VD4 (40 years)
900 MW (34 units)		done	2009 to 2020 (25 units done)	2019 to 2030
1300 MW (20 units)		done	2015 to 2024	2025 to 2034
1450 MW – N4 (4 units)	done	2019 to 2022	2029 to 2032	2039 à 2042

Numerous improvements have already been implemented on the existing NPPs, i.e.:

- Examples of improvements already implemented
- filtered containment venting device (U5-1986),
- H2 passive recombiners,
- containment sump strainers
- back up power supply (LLS, additional diesel or TAC / site),
- spent fuel pool make-up improvements
- seismic upgrade ...

PSR associated to VD4 900 will be the first to need the ASN authorization for the step beyond 40 years (initial design hypothesis)

- EDF Orientation file sent to ASN by end of 2013, with complements up to mid 2014
- Framing Advisory Group meeting in April 2015 ; French ASN position on review program received in April 2016

Ageing Management Program Process

- The major objective is to justify that all the components concerned by an ageing mechanism remain within the design and safety criteria.

- The AMP procedure, described in a generic guideline, is carried out in 4 main steps :
  - Selection of structures, systems and components (SSC) concerned by an ageing mechanism
  - Review of all the couples SSC / degradation mechanism selected by experts and synthetic analyses in Ageing Analysis Sheets (AAS)
  - Detailed Ageing Management Reports (DAAR) required for some sensitive components
  - Unit Ageing Analysis Report (UAAR)

- All these reports have to be prepared in agreement with the French regulation.

EDF Modernization program for existing NPPs

- **It will be monitored through a specific project, the "EDF industrial project" ("Grand Carénage") which:**
  - ✓ integrates all modifications issued from the different programs (PSR, Refurbishment program, post Fukushima and all other modification or maintenance programs) with a multi-annual vision
  - ✓ assures the monitoring off all aspects of the program: nuclear safety, availability, economic and financial dimension, industrial resources, internal resources and skills, logistic
  - ✓ Aims at operating the fleet well beyond 40 years, up to 60 years

Material R&D Program

The major objectives of the Materials R&D Program are:

- To ensure that all the pertinent ageing mechanisms are evaluated (including possible mechanisms),
- Increase the knowledge in the areas and technical fields when required,
- Avoid penalising extrapolations due to a lack of data,
- Acquire needed data for equivalent 60 year ageing to check they remain within the design and safety criteria.

Approach:

- Ageing R&D Programs for all areas sensitive to ageing or degradation mechanisms
- Representative materials

  (archive or sampled materials or removed components or dedicated mock-ups)
- Ageing in furnaces (thermal ageing) or experimental reactors (irradiation) or loops (corrosion)
- Materials tested after equivalent 60 years ageing time,
- Mechanical data (toughness, tensile, fatigue...), CSC data (initiation and propagation), corrosion rate, etc.

Main Materials R&D Programs
Mechanisms taken into account (1/2)

1 Embrittlement mechanisms

- **Neutron embrittlement : RPV steel and welds, internals**
- **Thermal ageing : CASS, Austenitic SS welds and dissimilar welds, Martensitic Stainless Steels, Low Alloy Steels and C-Mn steels**

2 Corrosion

- **Stress Corrosion Cracking** *(Irradiation Assisted)* **of RPV Internals**
- **Stress Corrosion Cracking of cold work austenitic Stainless Steels** *(316L)*
- **Stress Corrosion Cracking of Nickel base alloys: Alloy 600 and welds**
- **Boric Acid Corrosion…**
- **FAC in secondary circuit,**
- **…**

Main Materials R&D Programs
Mechanisms taken into account (2/2)

3 Fatigue

- Low Cycle and High Cycle fatigue (Thermal Fatigue)
  - Mixing areas
  - Better evaluation of stratification loads with a Fatigue Assessment Device
- Environmental Assisted effects:
  - Mainly for austenitic stainless steels

4 Degradation with loss of material: Wear

- Impact Sliding Wear

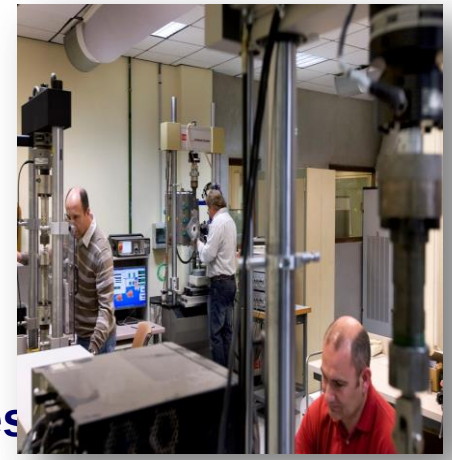
5 Degradation of non metallic material

- Polymers: Physical Ageing, Chemical Ageing…
- Concretes:
  - Swelling (Alkali Silicate Reaction…)
  - Creep…

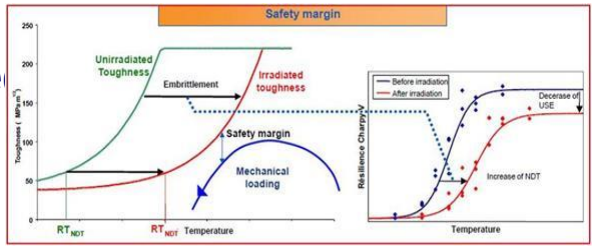
The Materials Ageing Institute for R&D relative to plant life extension

- **Need for Predictive Capability for**
  - **- Inspections**
  - **- Mitigations**
  - **- Replacement**
- **Through Mechanistic understanding of ageing processes**

Materials Ageing Institute



- **11 Members (Utilities...) representing 66% NPPs**
- **80 Researchers and technicians involved**
- **20 universities / scientific institutes associate**
- **11 M€ annual budget in 2013**
- **35 M€ total EDF's Investment (2008-2016)**
- **250 participants yearly in the E&T program**
- **12 main projects**



Conclusion and perspectives on EDF LTO strategy

LTO will bring additional value to existing NPPs as a tool to produce safe, reliable, economical, clean and low carbon electricity,

LTO constitutes a challenge which multiple aspects. Among the most importants:

- Continuous improvement of safety to reduce gaps with new NPPS, mainly through PSR process
- Adequate management of Ageing and obsolescence

Lifetime extension (up to 60Y) should be reasonably achieved owing to :

- Adequate maintenance strategy and program
- Complementary analysis for non-replaceable components : RPV and containment building.
- Extensive R&D Programs to support this analysis

Thank you
for your attention