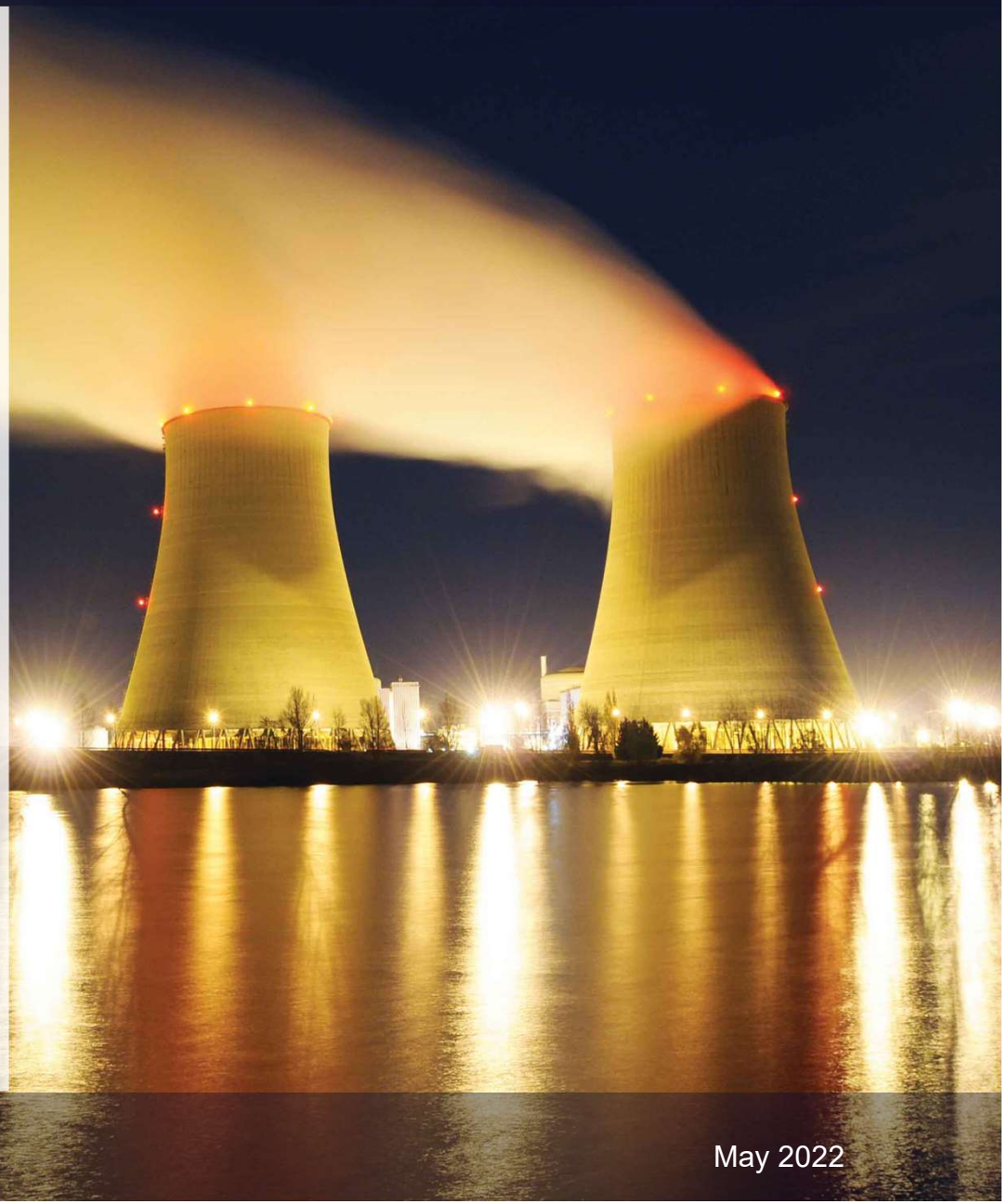
Evolution of EDF ageing management in the frame of LTO

NRG Conference LTO Amsterdam



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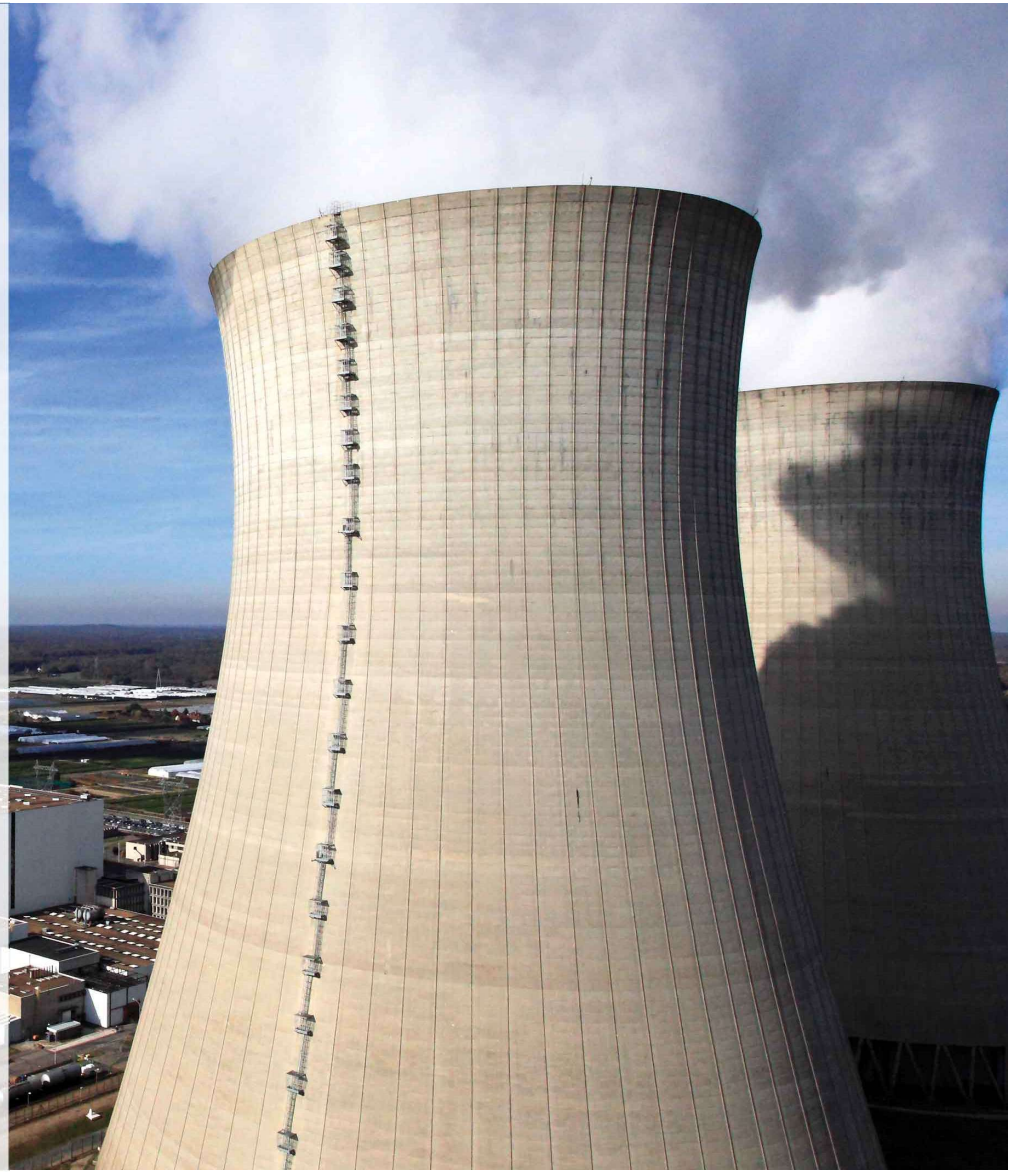
FRENCH NUCLEAR FLEET SPECIFIC CONTEXT

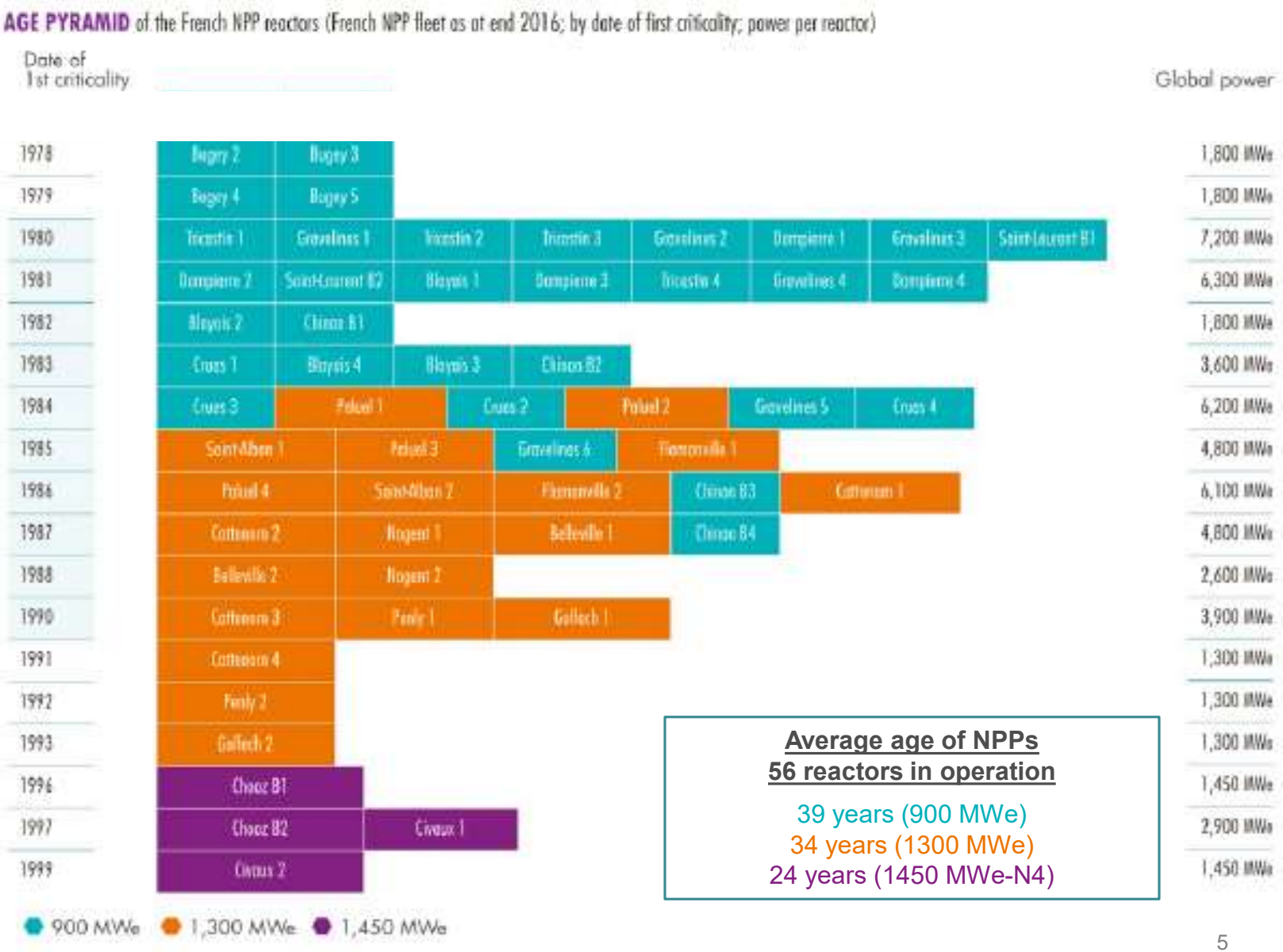


French Nuclear Fleet specific context

- **56 reactors in operation**
  - ✓ **18 sites**
  - ✓ **Capacity : 61,4 GWe**
- **✓+ 1 reactor under construction**
  - ✓ **FLA 3, 1600 MWe EPR**

900 MWe PWR series
1300 MWe PWR series
1450 MWe PWR series
1600 MWe PWR series
(under construction)

French Nuclear Fleet specific context

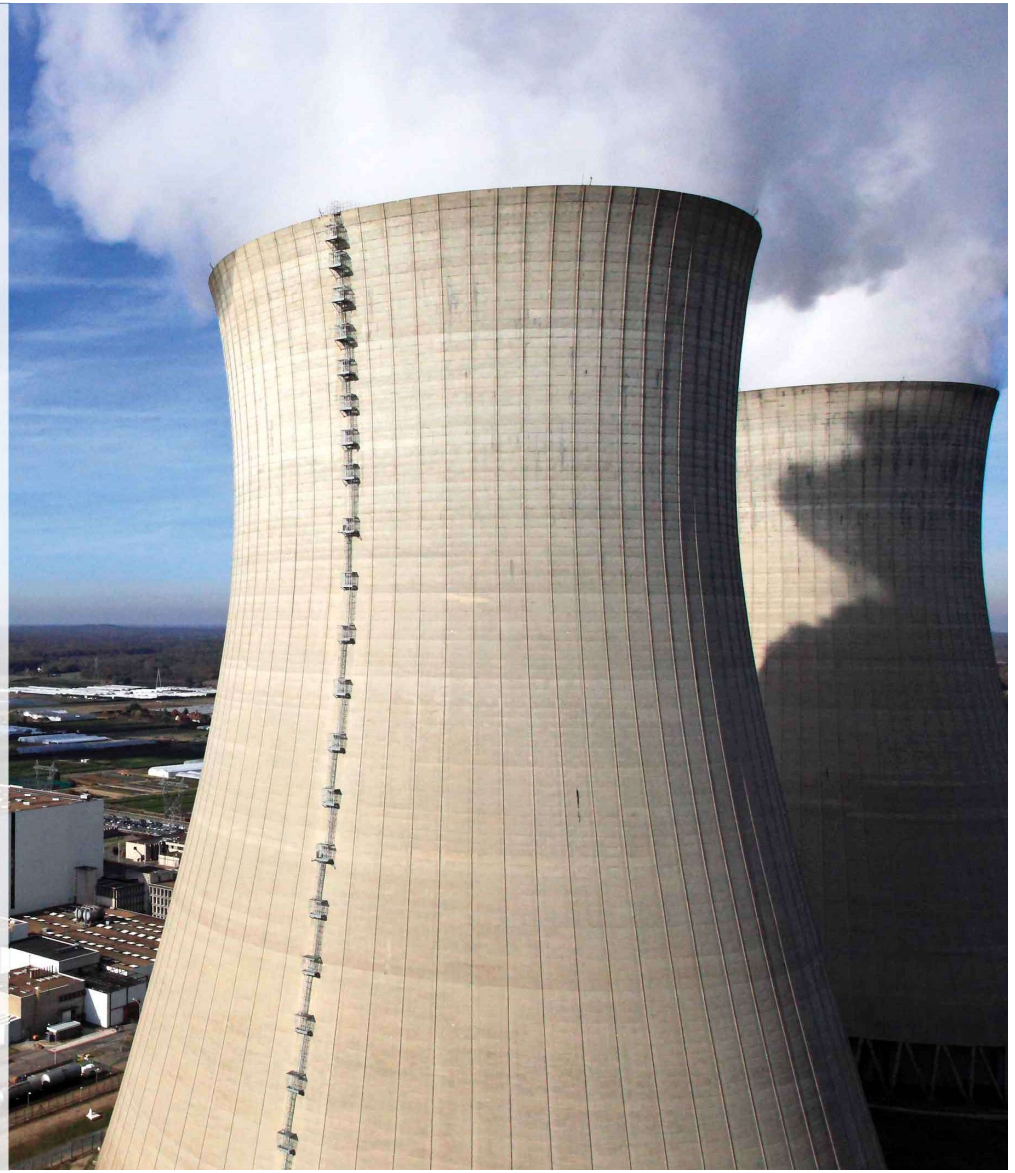


Average age of NPPs
56 reactors in operation

39 years (900 MWe)
34 years (1300 MWe)
24 years (1450 MWe-N4)

2

Ageing Management in the frame of LTO



Ageing Management Process

Description of the Ageing Management process

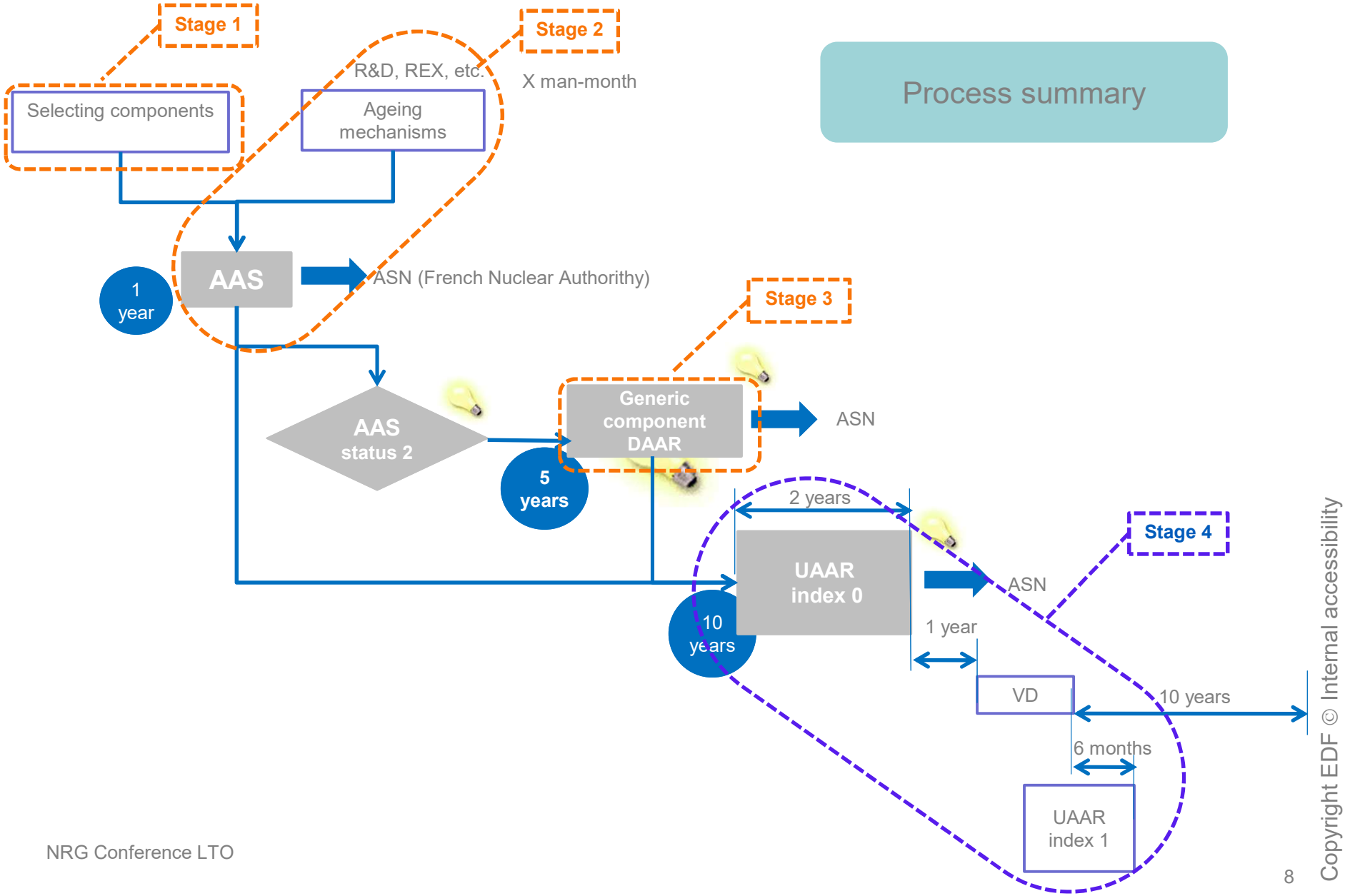
The process of ageing management relies on 4 key stages:

1. Selection of systems, structures and components (SSC) sensitive to ageing
2. Examination of all couples SSC /ageing mechanism: Ageing Analysis Sheet (AAS)
3. Detailed Ageing Analysis Report (DAAR) for most sensitive SSCs
4. Establishing a Unit Ageing Analysis Report (UAAR) valid for the decade following the 10 years outage of each unit

Stages 1 to 3 completed at **corporate level per plant series (900/1300 MW).**

Stage 4 completed by the plant and specific to the unit.

Ageing Management Process



Ageing Management Process

Identification of SSC sensitive to ageing, per plant series at corporate level

- **IPS : SSCs important to safety**
- **Non-IPS SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions**
- **Non-IPS SSCs which, with respect to the PSA make a significant contribution to limiting the core melt risk**
- **EIPR : SSCs important for conventional risks protection (for LTO)**
  - Elements whose failure would have consequences for functions related to non-radiological accidents (containment of dangerous substances, protection of people/environment against effects of dangerous phenomena)
  - Example : ultimate sump
- **EIPI : SSCs Important for protection from inconveniences (for LTO)**
  - Elements whose failure would have consequences for the functions related to inconveniences (health impacts, environmental impacts)
  - Example : rejection flow control valve, flow meter, pumps, chemical and/or radioactive liquid rejections
- **Other SSCs that are credited in the safety analyses (deterministic/probabilistic) as performing the function of coping with certain types of events (for LTO)**
  - SSCs needed to cope with internal events: internal fire and internal flooding;
  - SSCs needed to cope with external hazards : earthquake, external flooding, and external fire

Ageing Management Process

AAS review per plant series by corporate operating and engineering departments

- **AAS drafted for each couple SSC / ageing mechanism (potential or proven)**
  - gives an **overview** of SSCs ageing management.
  - used to control ageing management in the light of OPEX, maintenance/ISI/surveillance provisions, repairability and replaceability
  - reviewed every year and, if necessary, updated.
- **Input data**
  - development of maintenance, ISI, surveillance programs, processing of obsolescence
  - analysis of events from national and international OPEX
  - R&D activities, incorporating experience feedback from collaboration and international exchanges: IAEA, EPRI, OECD, WANO, other utilities, etc.
  - comments from Units, particularly NPP performing their UAAR

Ageing Management Process: Ageing Analysis Sheet

➢ Ageing management documents issued at corporate level

- Maintenance / ISI / surveillance programs issued by **corporate operating department** per plant series
- TLAA issued by **corporate engineering department** per plant series

➢ Benchmark with IAEA standards

- Modification of AAS template because the EDF document structure is different from that of IAEA
  - to comply as closed as possible to AMP structure
  - to integrate AMP attributes
  - to become an AMP summary identifying documents relative to the attributes
- Benchmark with IGALL AMR to check completeness of EDF scoping
- Identification to TLAA equivalent documents (6 criteria of a TLAA not always specified)

Ageing Management Process

Stage 2: Ageing Analysis Sheet

FICHE D'ANALYSE DE VIEILLISSEMENT *AGEING ANALISYS SHEET*						N° Fiche*	*XXX-YY-ZZ*		
						Indice*	*Index*		
						Date*	*Date*		
						Référence base de connaissance	*Mechanism (Capcov)*		
DIP*	Rédacteur	*Redactor's name 1*	Unité	*Unit*	Vérificateur	*Controller's name 1*	Unité	*Unit*	
DPN	Rédacteur	*Redactor's name 2*	Unité	*Unit*	Vérificateur	*Controller's name 2*	Unité	*Unit*	
Palier(s) / Tranche(s)	*Serie (900 or 1300) or specific NPP*								
Composant / structure	*SSC (System / Structure / Component)*								
Élément / zone	*Location*								
Mécanisme	Acronyme	*acronym*	Mécanisme	*Ageing mechanism*					

Evolutions des trois derniers indices →

Cocher s'il y a changement de méthodologie
Cocher ici s'il y a évolution des données amont

Indice	Date	Motif du changement d'indice	Modifications apportées		
					X

Ageing mechanism knowledge basis = Capcov basis
EDF basis about ageing mechanism, isued at corporate level by R&D Department

Ageing Management Process: Ageing Analysis Sheet

Analysis	Answer / Justification / Comment	Reference
Safety class	*Safety class*	*Document references for each item*
Description of the ageing mechanism	*Description of the ageing mechanism*	
Material / environment	*Material / environment*	
Associated ageing effects	*Associated ageing effects*	
Design provisions to minimize ageing effects	*Design provisions to minimize ageing effects*	
Justified operation period (TLAA notion)	*Justified operation period (TLAA notion)*	
Proven mechanism / OPEX / proven ageing effects	Yes/no ***"Yes":*** *if the ageing mechanism and/or associated damages are proven (i.e. recorded in a French NPP or in a foreign similar PWR plant)* ***"No":*** *if the ageing mechanism and associated damages are potential* ***"Irrelevant":*** *if the ageing mechanism is irrelevant for the considered SSC in the considered operation conditions* *Description of the ageing mechanism and/or effects in OPEX / occurrence*	

Ageing Management Process: Ageing Analysis Sheet

Analysis	Answer / Justification / Comment	Reference
Operating and maintenance provisions In-service inspection / surveillance / water chemistry programs	Appropriate / Improvable / Difficult to improve *Current operation / maintenance / in-service inspection / monitoring actions:* ***"Appropriate":*** *if these actions enable the detection and treatment of the damages* ***"Improvable":*** *if it is possible to implement modifications of the existing actions or additional actions to make them more appropriate for the target date.* *If it is not possible, the operations and maintenance actions are considered* ***"difficult to improve"*** *Description of the actions performed to manage SSC ageing (maintenance, monitoring, in-service inspection, periodic testing, diagnostics, replacement programs…)*	
Mitigation actions	*Mitigation actions*	
Acceptance criteria	*Acceptance criteria for continued operation*	

Ageing Management Process: Ageing Analysis Sheet

Repairability of the SSC	*Description of repair activities*	
Implementation difficulty	Low / Medium / High ***"Low difficulty":*** *if a procedure already exists or would be easy to design and to implement, without complex qualification, with good accessibility conditions and significant chances of success* ***"High difficulty":*** *if the procedure is not available and its development requires significant anticipation because:* - *its creation or implementation is complex,* - *or it requires a long, or never realized qualification,* - *or accessibility is difficult,* - *or the chances of success without anomaly are difficult to guarantee.* ***"Medium difficulty":*** *neither low nor high*	
Obsolescence risk	*Obsolescence risk*	

Ageing Management Process: Ageing Analysis Sheet

Replaceability of the SSC	*Replaceability of the SSC*		
Implementation difficulty	Low / Medium / High ***"Low difficulty":*** *if a procedure already exists or would be easy to design and to implement, without significant questioning of the safety report or existing design documents, without complex qualification, with good accessibility conditions and significant chances of success* ***"High difficulty":*** *if the procedure is not available and its development requires significant anticipation because:* - *its creation or implementation is complex,* - *or it requires a long, never realized qualification,* - *or accessibility is difficult,* - *or the chances of success without anomaly are difficult to guarantee.* ***"Medium difficulty":*** *neither low nor high*		
Obsolescence risk	*Obsolescence risk*		
Status	*(*)*	Justification	*Justification: if the proposed status is different from the one determined by the grid of the methodological guide*
Further actions (status 1 or 2)	*Further actions to implement to demonstrate ageing management*		

Ageing Analysis Sheet: status determination

STATUS	*Ageing mechanism : **Proven***			*Ageing mechanism **Potential***		
Operations and maintenance actions	*Appropriate*	*Improvable*	*Difficult to improve*	*Appropriate*	*Improvable*	*Difficult to improve*
Reparability AND replaceability : "High difficulty"	***2***	***2***	***2***	***0***	***1***	***2***
Reparability OR replaceability : "Low or Medium difficulty"	***0***	***1***	***2***	***0***	***1***	***1***

0 : Ageing controlled → no further actions

1: Complementary actions needed to confirm aging management

2 : Production of a DAAR

Ageing Management Process: Stage 3 DAAR

DAAR issued per plant series by corporate operating and engineering departments

- To deepen the analysis of operating aptitude of one (or several) SCC for which one (or several) AAS are in status 2
- To identify, if necessary, additional studies, R&D programs, maintenance / repair / replacement programs to be developed.

DAAR content:

- **Design provisions :** regulations, codes & standards, specifications, design rules, safety functions
- **Description and OPEX:** design, materials, manufacturing processes, water chemistry, operating conditions and feedback
- **Ageing mechanisms :** scientific knowledge, acceptance criteria, mitigation, maintenance, in-service inspection and monitoring
- **Industrial capacities :** repair, replacement, obsolescence
- **Conclusion on the ability of the component to continue its operation :** complementary ageing management program, including maintenance ,ISI, modification, operating conditions, R&D actions.

DAAR reviewed every 5 years (± 1 year)

Ageing Management Process

Stage 3: DAAR (Detailed Ageing Analysis Report)

500 AAS for 900 MW serie

including

7 in status 1

31 in status 2

11 DAAR

Reactor Pressure Vessel

RPV Internals

Pressurizer

Steam Generator

GMPP (primary pumps)

Primary pipes

Cables

Electrical penetrations

I&C

Containment building

Civil engineering structures

Ageing Management Process

Stage 4: Unit Ageing Analysis Report (UAAR)

UAAR issued every 10 years by NPP with corporate operation department support

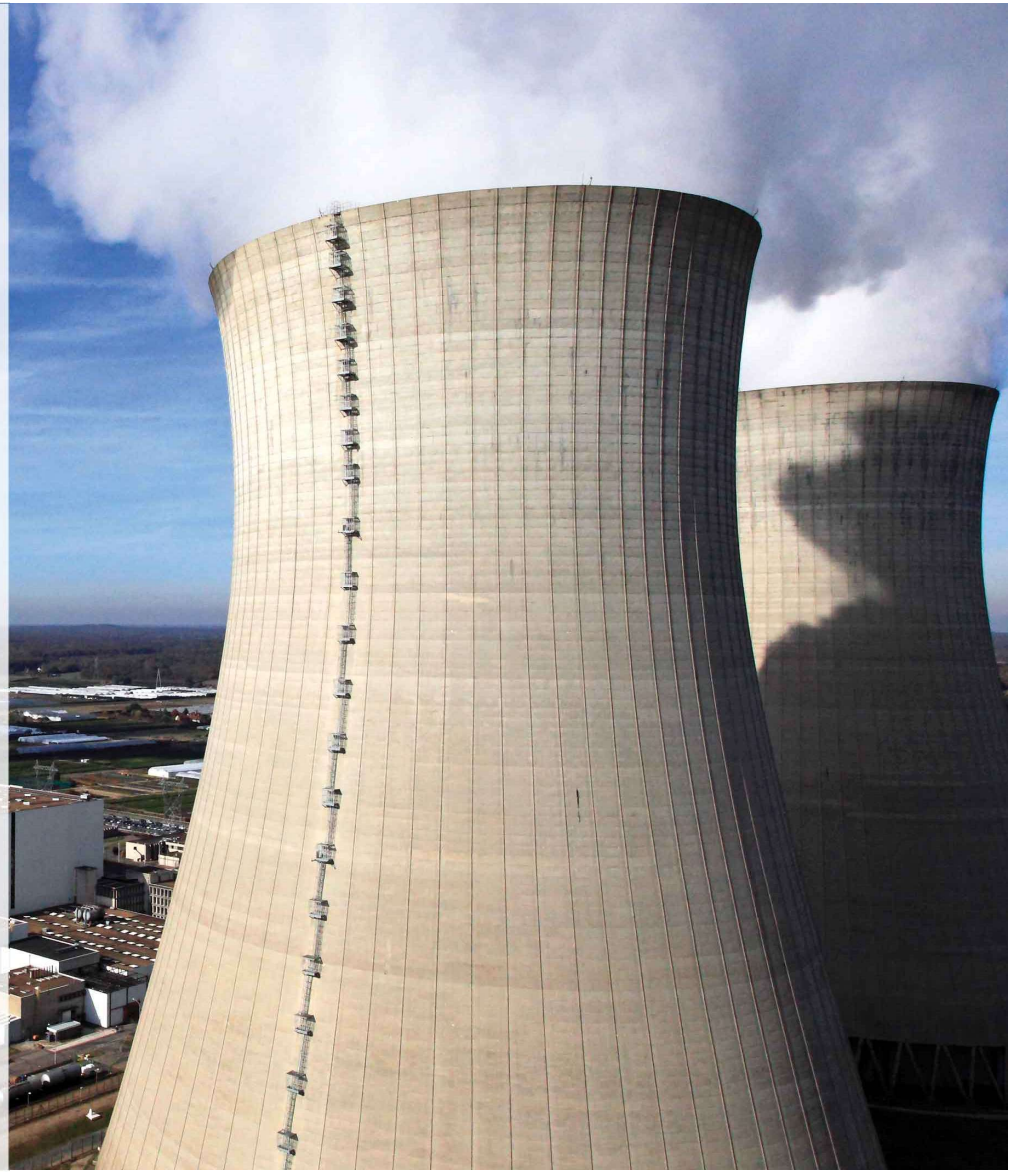
Objective of the UAAR:

- Analysis of the plant situation about ageing management based on the analysis of AAS / DAAR
  - identification of design specificities, manufacturing and operating elements not taken into account by generic documents
  - Inspections results, deviation sheets, OPEX
  - verification of implementation of corporate AMPs specified in AAS, if necessary implementation of local AMPs (PLMPs)
- Integration of unit specificities (SSCs, modifications….)
- Issuance of its **specific plant ageing management program (PLMV)** for the ten-year period associated with this outage = complement to UAAR
  - application of current operating and maintenance rules prescribed at corporate and local levels,
  - mitigation measures identified by the NPP during AAS analysis
  - specific actions to complement corporate ageing management: local AMPs, SSC replacement…
  - site particularities related to maintenance, design, operation: **about 1% of total ageing management**

Updated in the 6 months following the ten-years outage, completed by the results of the examinations and works performed during the outage.

3

R&D program to support LTO: example of 2 major projects



Sherlock Project

Examinamination of SG n° 2 of Cruas Uni

- Cruas 4: 900 MWe

- **~30 (calendar) years of operation**
- ~ 206 000 h Effective Full Power

- SG design: Areva 51B

- River water coolant

- SG removed from reactor building in April 2014
- SG is now in horizontal position in a storage building on Cruas site

Sherlock Project

- **Objective:**
  To improve understanding of SG ageing mechanisms

- **Project is a 10-year program of activities, in two phases**
  - Phase 1: NDT (ECT and VT), Decontamination, Specimen sampling
  - Phase 2: Laboratory Examinations

- **Specimen removals performed in an on-site storage building**
  - Removed SG samples (i.e., tubes, deposits, supports, etc.) will be examined in **EDF's off-site corporate hot laboratories**

- Investigations in hot laboratories: end of 2022 → at least 2024

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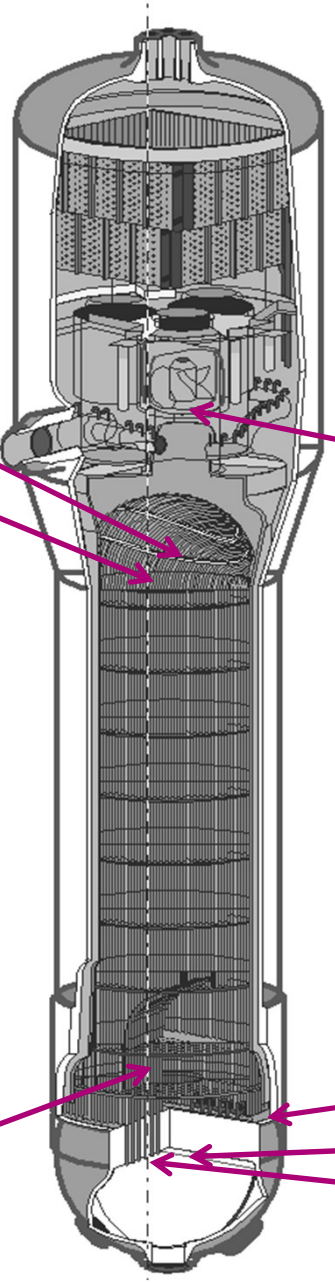
Sherlock Project: scope



Vibratory issues

Deposit and clogging
Mapping – different TSP
Chemical analyses

Primary side corrosion

Secondary side corrosion
No SCC expected

Fouling

Internal parts
Tie rods: metallurgical exams
Other: visual inspection

Wear
AVB/tube

Hard sludge

690 Plugs

Welds

Vercors PROJECT

VeRCoRs: Vérification Réaliste du Confinement des Réacteurs

Realistic Verification of Reactor Confinement Building

1/3 scaled PWR containment building

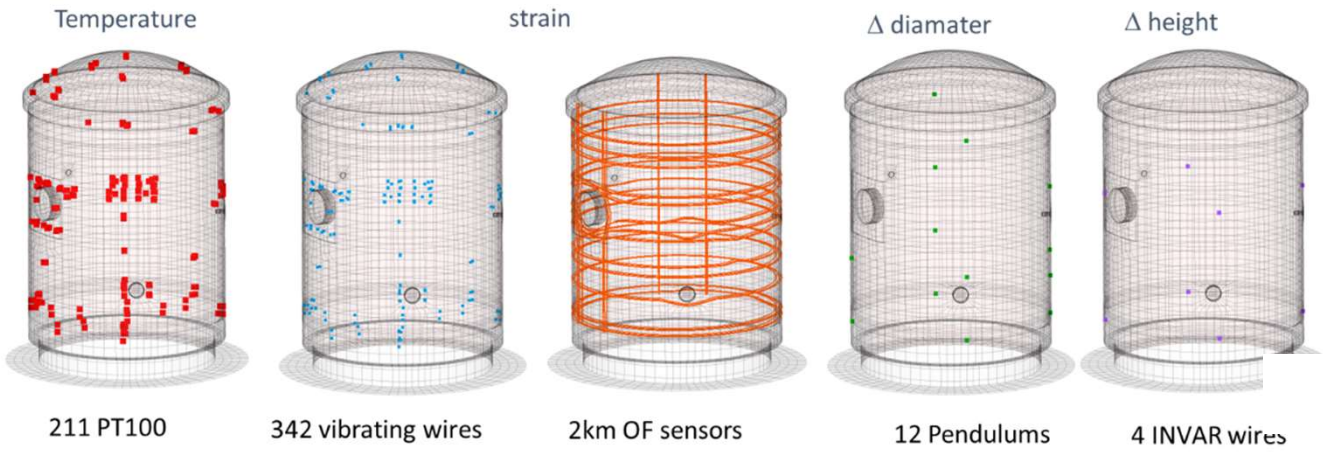
EDF Target :

- Increase understanding of prestressed concrete ageing
- Demonstrate EDF installation robustness
- Identify more precisely sensitive areas of reactor building

Vercors

An important monitoring effort

Measured variable	Sensor type	VeRCoRs mock-up	EDF fleet
temperature	PT100 probes	>200	30
strain	vibrating wires	>300	50
diameter variation	plumb-lines	4	4
length variation	invar wires	4	4
rebar strain	strain gages	80	-
water content	TDR	20	-
water content	Pulse	20	-
strain+temperature	optic fiber (OF)	2km	-



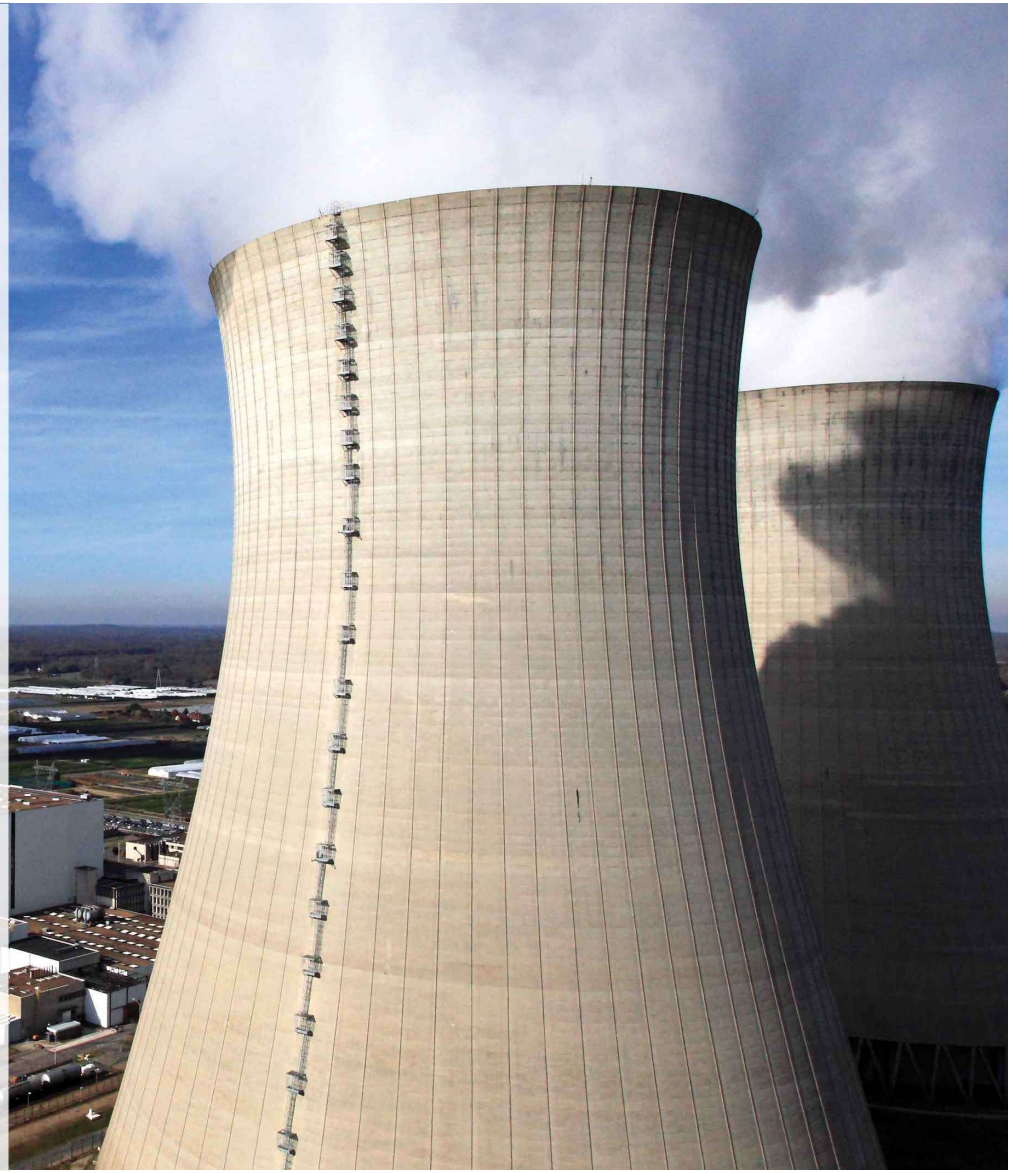
Vercors

Main objectives for ageing management:

- Better understandind of ageing phenomena
  - Loss of prestressing
  - Drying
  - Creep and shrinkage
- Better understanding of leakage phenomena
- Improvement of FEM
- Measurement improvement
  - Optical fiber
  - Detection of cracking (depth and opening)
  - Leakage detection
  - New device and new NDE assessement

4

Conclusion



Ageing Management Process in the frame of LTO

Conclusion

- EDF ageing Management Process performed at **corporate and plant levels**
- The majority of activities are defined at **corporate level**
- Ageing management process evolution with benchmarks
- LTO supported by an important R&D program