ATOMEXPO

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EDF PWR Fleet Overview

Maintenance and Long Term Operation strategy

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Outline

EDF - leader in Low carbon generation

Nuclear generation experience and strategic areas

Operation methods and maintenance of the nuclear fleet

Long Term Operation - a multi-facets challenge
Regulatory ramework and periodic safety reassessment (PSR) process
Post FKH action plan & Main steps of deployment
EDF industrial strategy and safety goals
Ageing management and R&D
As a result

Some economic aspects

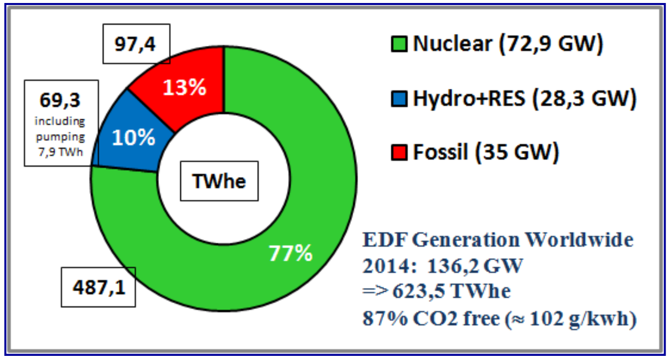
As a conclusion

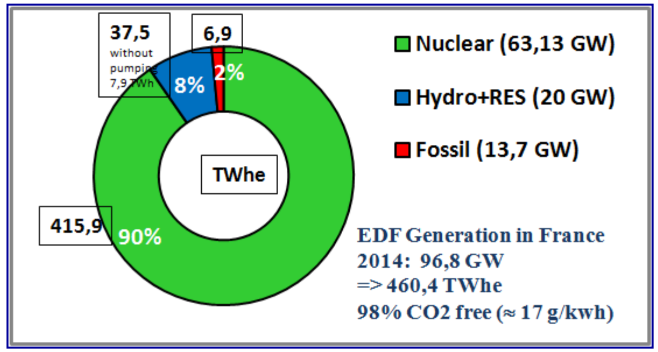
EDF - A Global Energy Utility - Leader in Low Carbon Generation

Key figures 2014 - EDF Group Worldwide and EDF SA France

- 38,5 million **customer accounts** (28,2 in France)
- **623,5 TWhe electricity** generated
- 158 161 employees (132 107 in France)

- **Sales**: 72,8 bEu 55% France; **45% abroad**
- **Ebitda**: 17,3 bEu (debt ratio 2) 70% France; 30% abroad
- **CO_2 emissions** (elec+heat): Group **102 g/kwh**; EDF SA **17 g/kwh**





Total France: 540,6 TWh; 129 GW
Nuclear: 415,9 TWh; 63,2 GW
Fossil: 27 TWh
(Coal 8,3; Gas 14,3; Oil 4,4)
Hydro: 68,2 TWh; 25,4 GW
Wind: 17 TWh; 9,12 GW
Solar: 5,9 TWh; 5,3 GW
Others: 6,6 TWh (5,1 RES)

EDF Group worldwide net generation mix:
136,2 GWe => 623,5 TWh 87% CO_2 free

EDF SA France net generation mix:
96,8 GWe => 460,4 TWh 98% CO_2 free
(total France 540,6 TWh, EDF part 85%, nuclear 77%)

- **Nuclear expertise:** more than 30000 staff (Operation: 25000; Engineering: 5000; R&D: ≈ 1000 eq.)

- **Solidly anchored in Europe (**France, Italy, Poland, UK...); **industrial operations in China, Brazil and USA**

- **Renewable**: a developing activity worldwide (Wind: 4,4 GWe => 9,8 TWh in 2014)

- **Natural gas**: 20 bm3 in EU; France: 19,6 TWh (4,7% market share); Italy: 5,7 bm3 60 TWh (13,6%); UK: 28 TWh (5%); Belgium: 13,2 TWh (18%)

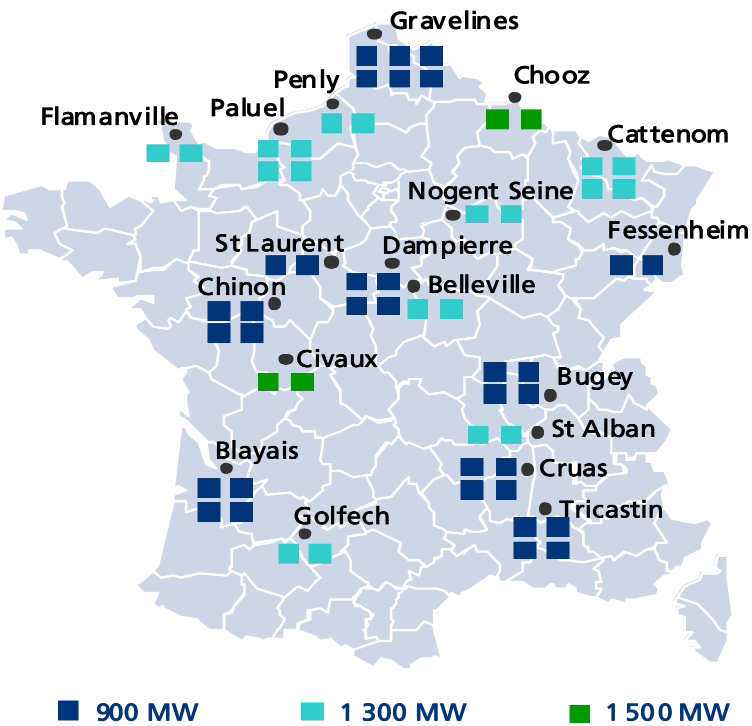
Nuclear generation

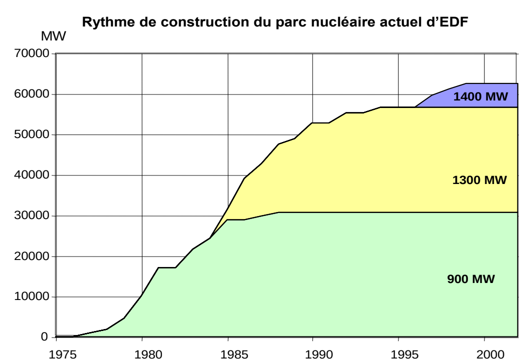
Experience & Strategic areas

Fessenheim NPP - 2 units 900 MW
Commissioned in 1977

EPR construction at FLA3

EDF Nuclear facilities in France





58 Pressurized Water Reactors (PWR)
19 sites: 63,2 GW => 415,9 TWh in 2014;

Priority to safety: **- Internal oversight structures**
- IAEA Osarts & WANO peer reviews

Three standardized series:
=> a major safety and economic benefit

- 900 MW: 34 units, 31 GW (average age 33 years)
- 1300 MW: 20 units, 26 GW (average age 26 years)
- 1500 MW (N4): 4 units, 6 GW (average age 14 years)

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: 29 years (13 to 37 years)
- Experience feedback: ~ 1660 reactor years
- Periodic 10 years Safety Reassessment process

=> Long Term Operation: technical goal up to 60 years

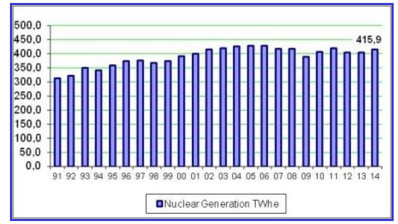
EPR under construction: Flamanville 3

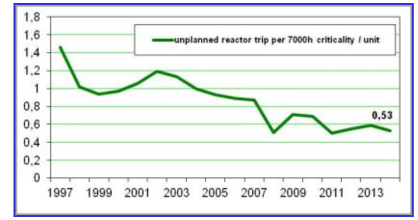
Decommissioning program: 9 reactors
(6GGR, HWGCR Brennilis, Creys Malville, Chooz A...)

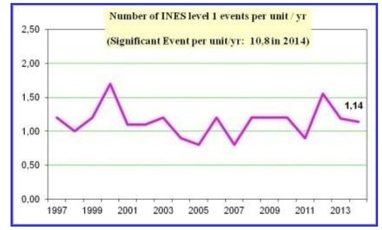
EDF Nuclear Generation in France and abroad

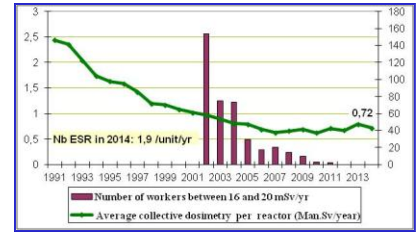
- **EDF in France: 63,2 GWe => 415,9 TWh in 2014**

  availability kd : average 80,9% (top10: 91 to 99,5%); kif: 2,4%
  kp: 75,2%; ku : 93% (frequency control, load follow..)
  Load rejection success rate: 88% (average)







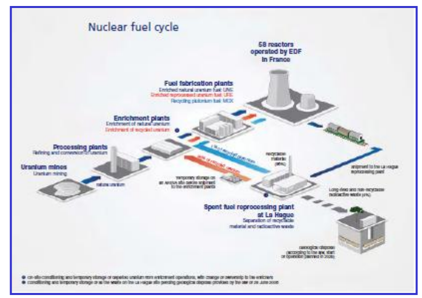


Main technical issues:

- Steam Generators replacement (replaced in 26 units)
- generator stators, main transformers …
- maintenance (AP913..), outage management (COPAT..)
- preparation of a major refurbishment programme (LTO...),
- post FKH action plan

A sustainable fuel cycle: reprocessing, recycling,

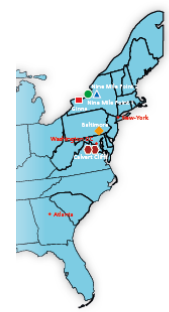
- Use of MOX fuel (on 22 units 900 MW; 30% core) & REPU fuel
- Vitrification of HL Waste (0,86 m3/TWh) & storage
- CIGEO project: HLW future disposal



- **EDF Group abroad : nuclear** (2014)

- **UK: EDF Energy : 8,9 GW nuclear => 56,3 TWh** (14 AGR, 1 PWR at Sizewell)
- **Other international participation in nuclear generation: ≈ 2,9 GWe**

  5 units (49,99%) in US with CENG: Calvert Cliffs 1/2, Ginna, Nine Mile Point 1 & 2(82%) (BWRs)
  Tihange 1 (50%) & other participations in Belgium (EDF Luminus) & Switzerland (Alpicq)

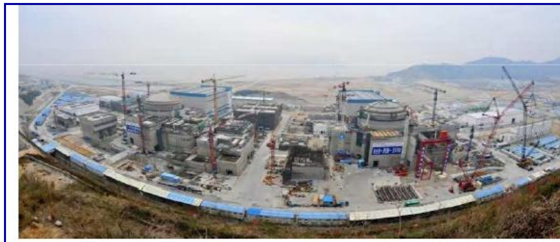


Strategic areas
Preparation for the future

Implementation of technical conditions for the extension of the operational lifespan of NPPs significantly beyond 40 years, through periodic safety reassessment process:
i) continued safety improvements & integrating lessons learnt from FKH
ii) implementation of a preventive policy with respect to ageing and obsolescence

EPR construction at FLA3

Building a first EPR unit in Flamanville and drawing experience feedback;



Construction of 2 EPR at Taishan with CGN

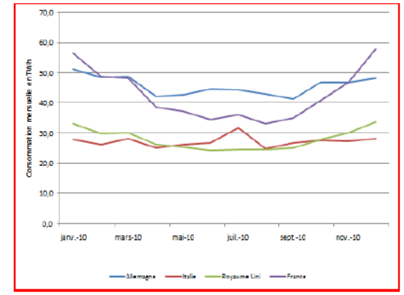
Optimising EPR design and construction through experience feedback with Areva and development of new models of GEN3 reactors (1000 & 1500 MW)

Being a major player in the international development of Nuclear Power
- International cooperation: WANO, IAEA, WNA, ENEF, R&D (EPRI, JAEA..)
- New Nuclear Build projects: China (2 EPR with CGN), UK (EPR GDA, HPC)
- Prospects in Poland, Saudi Arabia, RSA...

HPC EPR project in UK: GDA approval December 2012

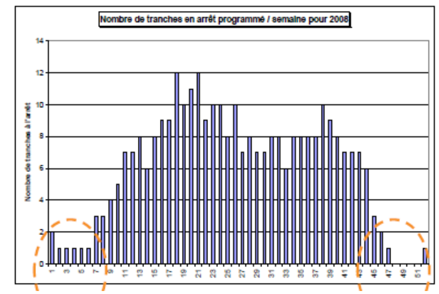
Developing the skills and competences, and industrial capabilities, needed to achieve these objectives

Operation methods and maintenance of the nuclear fleet
Generation cycle and scheduled shutdowns



In order to adapt to seasonal consumption needs in France, with full availability in winter time, **half of the units (900 MW series) have an operating cycle of about 12 months and another half (1300MW, 1500 MW series...) of about 18 months.**

All units are operated in load following mode



Two types of planned shutdowns are alternated after each generation cycle:

- an **ordinary shutdown for refuelling** only and light maintenance (≈ 35 days)
- a **partial inspection shutdown for refuelling and maintenance** (≈ 70 days)

Every ten years, the plant is shut down for a ten-year inspection, associated maintenance and modifications issued from ten years safety reassessment process (≈ 110 days)

- unloading of spent fuel and refuelling;
- hydro-pressure tests of primary and secondary circuits, containment building leaktightness pressure test, and inspection works on the reactor vessel;
- modifications, in the framework of the ten-year safety reassessment process (=> further);
- other specific maintenance operations including major component renovation.

Operation methods and maintenance of the nuclear fleet
Generation cycle and scheduled shutdowns

Main improvements in the management of maintenance activities:

- **reduction in fortuitous outages** (2.4% in 2014, down from 2,6% in 2013), thanks to a proactive maintenance strategy implemented since 2007 with renovation and major component replacement;

- **reduction in the average time for outage extension periods beyond schedule** (divided by two in 2014) through stabilizing routine maintenance during outages, improving the quality of the preparation of maintenance work and reinforcing controls of restart operations, with the implementation, for each outage, of an Operational Centre for Outage Management (COPAT) and the deployment of a new information system ("SDIN").

Regarding the organisational aspects of routine maintenance, EDF continues to deploy the AP 913 method to improve reliability and develop equipment health checks that aim to reduce unplanned outage rates.

Operation methods and maintenance of the nuclear fleet
Generation cycle and scheduled shutdowns

In january 2015, the EDF board has approved a major refurbishment programme ("Grand Carénage") in order to further increase the level of safety and prepare for the extension to the fleet's operating time, with a total investment of 55 billion euros for the next 10 years for the 58 reactors.

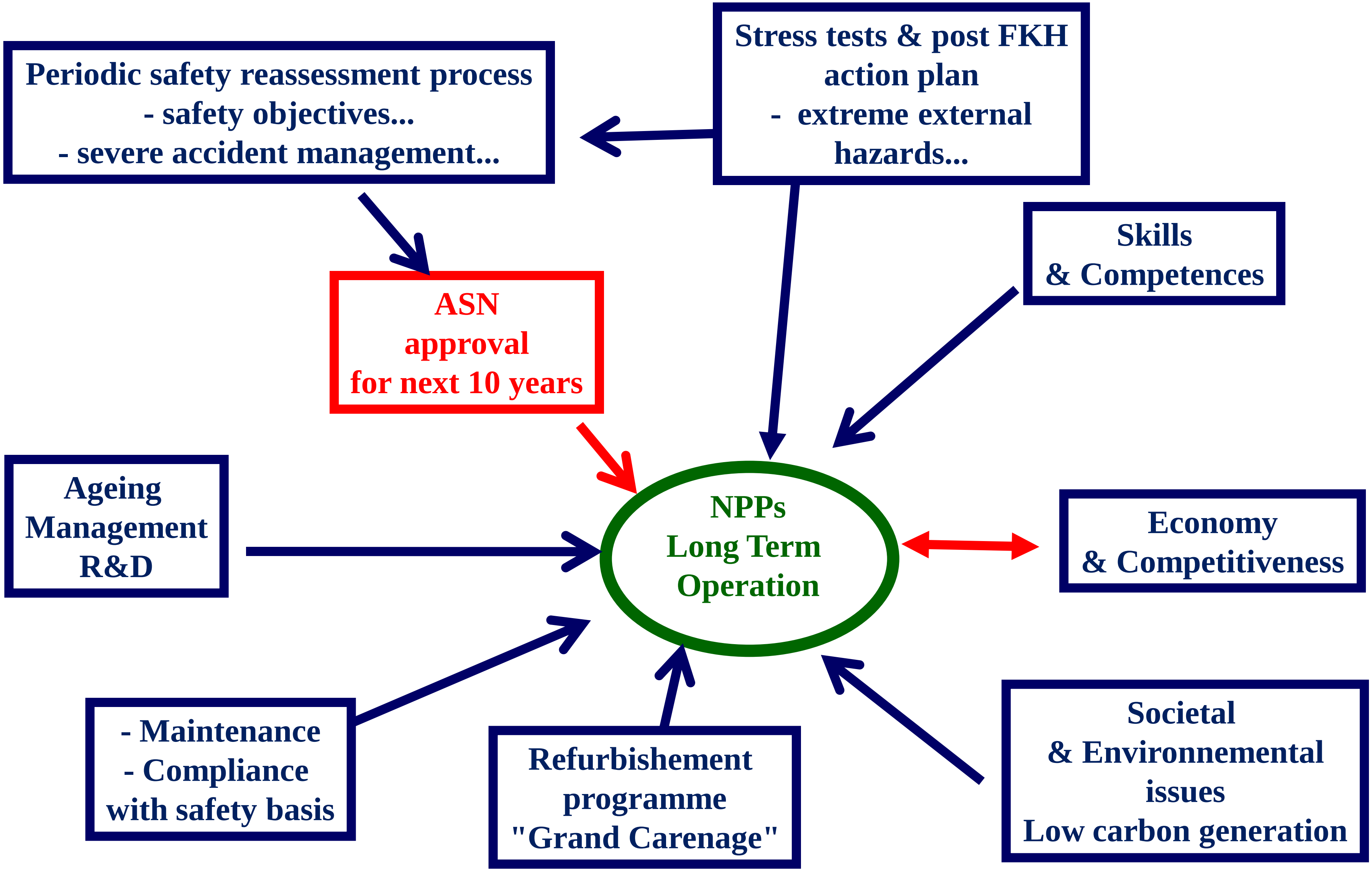
Accordingly, by 2015, the renovation or replacement programmes for large power plant components such as steam generators, alternators, transformers are set to continue.

By the end of 2014:

- steam generators were replaced in 26 units (between 1990 and 2014)
- alternator stators were renovated on 39 units (out of 49) showing insulation risks;
- preventive replacement of the main transformer poles is ongoing: 61 poles (out of 174) replaced.

The industrial project for the nuclear fleet will continue beyond 2015, included in the decennal outages of 900 MW series(VD3 and VD4 900), 1300 MW series (VD3 and VD4) and N4 series (VD2 and VD3).
This project will incorporate additional safety improvements (FKH action plan) as well as modifications allowing to extend the operation of facilities significantly beyond 40 years.

Long Term Operation: a multi facets challenge



The Regulatory Framework in EU and the French 2006 law (TSN)

- **The EU Safety Directive - requires that "... licence holders to regularly assess and verify, and continuously improve, as far as reasonably achievable, the nuclear safety** ... in a systematic and verifiable manner. "

- **WENRA safety objectives for new reactors to be "used as a reference to help identify reasonably practicable safety improvements for existing plants during PSRs".**

- **The french law (TSN) requires to perform every ten years a periodic safety reassessment of the plant,** "taking into account the best international practices, experience feedback, evolution of knowledge and rules applicable to similar plants " and **as a result to propose measures to improve the safety of the plant**.

- Periodic safety review (PSR) every ten years for each unit

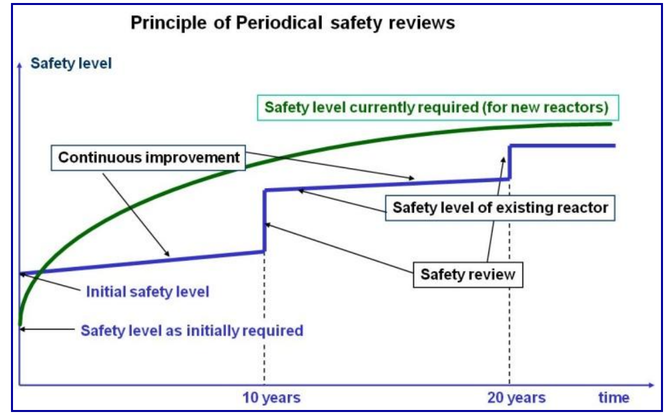
- No defined licensing lifetime but an agreement by the ASN, in view of the results and case by case analysis for each unit, to operate for another ten years period.
Generic approval for 900 MW units given in 2009 for operation up to 40 years and in March 2015 for 1300 MW series.

Safety is never granted and must be periodically reassessed

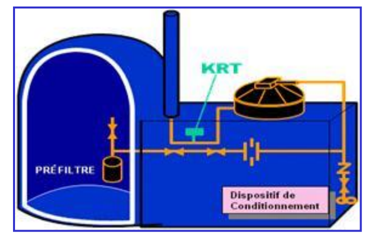
=> A comprehensive approach to maintain and improve, as far as reasonably achievable, the safety of NPPs

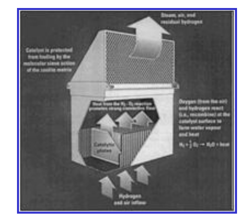
=> The basis to establish the ability for long term operation, under ASN control

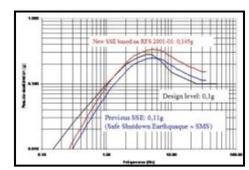
=> Need for a specific and integrated organization for long term operation

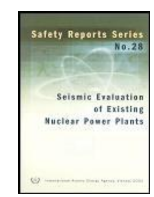


=> Numerous improvements already implemented
(TMI, Tchernobyl, Blayais storm 1999, heat wave 2003 ...):
- filtered containment venting device (U5-1986),
- state oriented EOPs, man-machine interface,
- H2 passive recombiners,
- containment sump strainers
- back up power supply (LLS, additional diesel or TAC / site),
- spent fuel pool
- flooding & seismic reassessment (spectrum);
- prevention and mitigation of severe accident & management;
- natural external hazards, classic risks, dosimetry....









Periodic Safety Reviews: the key to Plant Lifetime Management

Every 10 years, a safety reassessment process is performed for each standardized series, with two main aspects:

i) **Compliance assessment** with existing safety basis, checking and inspections, assessment of ageing mechanisms to manage fitness for LTO service

ii) **Reassessment and updating of the licensing basis** (internal/external events, severe accidents, PSA...), taking into account experience feedback, new knowledge or evolutions, best international practices & new requirements

=> As a result, a new safety referential and an improvement programme (backfitting and modifications, documentation, training...) is proposed to ASN

=> An on going process for maintenance, preparation, strategic decision, studies, implementation :

- 23 units 900 MW have performed their VD3 (end 2014);
- VD3 will begin on 1300MW units at Paluel (Generic approval by ASN in March 2015)

	VD1 10 years	VD2 20 years	VD3 30 years	VD4 40 years
900 MWe 3loops (34)	Done	Done	2009 to 2020	2019 to 2030
1300 MWe 4 loops (20)	Done	2005 to 2014	2015 to 2024	2025 to 2034
1500 MWe	Done	2019 to 2022	2029 to 2032	2039 to 2042

A decennal vist (≈110 days) will include: (i) fuel refueling (as for normal outage (45 days) or partial visit (70 days)); (ii) hydraulic pressure testing, containment testing, vessel inspection; (iii) modifications associated with decennal safety reassessment; (iv) other heavy maintenance (replacement of big components like SGs, major refurbishment...)...

Measures decided following "Stress tests"

Need for a reinforced and shared objective worldwide : nuclear plants must be able to face extreme, beyond design, situations.

Objective :

prevent a severe accident or, should it occur, avoid long term contamination.

=> No large releases with long term contamination of large territories

(design objective for new reactors, to be addressed for existing plant through PSRs)

Main measures

- Enhancing robustness of systems designed to **protect plant facilities against external hazards** : earthquakes (≥ 1,5 SSE spectrum), flooding (+30% flow..), high winds, heavy rains, ...
- **Increasing water make-up** (to the reactor and to the spent fuel pools)
- **Increasing electrical power supply capacity** (new emergency diesel)
- **Minimizing radioactive releases in the event of a severe accident** : to avoid significant long-term contamination of surrounding areas, and to allow on-site severe accident crisis management,
- **Reinforcing site and national emergency organizations** (staff and equipments)

Key additional measures

- **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 (event involving multi-units), with adequate Logistics and **mobile back up equipment**,
- reinforcement of crisis management premises on site

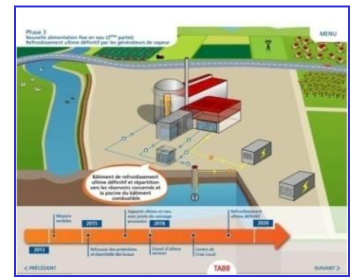
- **Implementation of a "Hardened safety core" of systems, structures and components designed to prevent large radioactive releases to the environment in extreme conditions considered by ECS reviews.**

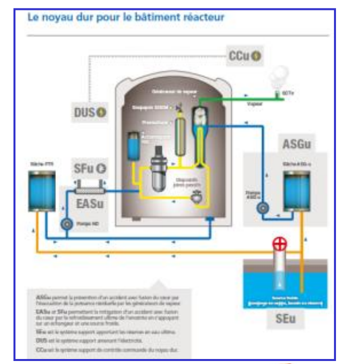
- protected against extreme external hazards exceeding the scope of the current design basis.,
- to increase prevention, mitigation and robustness beyond design

2015-2018: Increase the level of safety of French NPPs against extreme situations

2019 & beyond, in the framework of PSRs:

Reach a level of safety close to the best new reactors (GEN3)



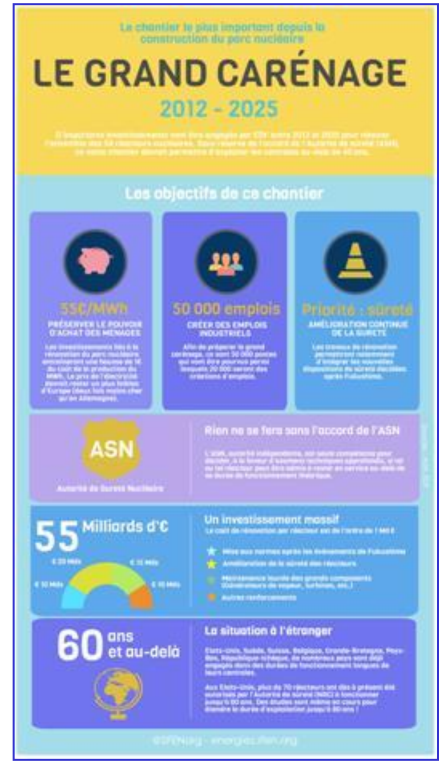


Long Term Operation

Practical implementation and Challenges

EDF's industrial strategy is to operate the fleet well beyond 40 years in optimal conditions of safety and performance,

This target is consistent with trends observed around the globe for similar technologies, up to 60 years (US: 73 units out of 100 have been granted a license renewal up to 60 years).



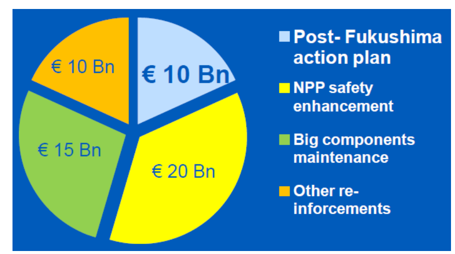
To achieve this goal, EDF works in continuity with the safety reassessment process which has been implemented since the beginning:

- EDF has implemented industrial and R&D action plans.

- Actions are undertaken to renew major components, through a major refurbishment programme or "Grand carénage", in connection with industrial capabilities and suppliers (SGs replacement, generators, main transformers..)

- Solutions being studied to demonstrate the capacities of non-replaceable equipment (reactor vessel and containment) to operate for up to 60 years

A massive investment:
55 Bn Eu over 10 years

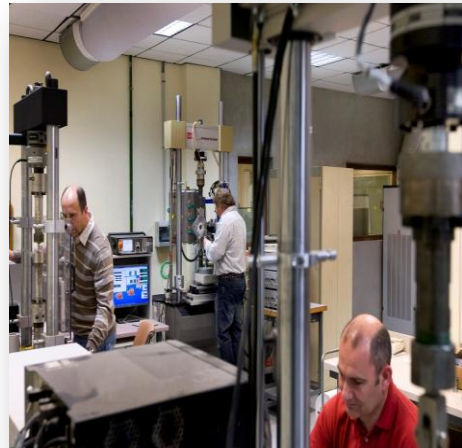


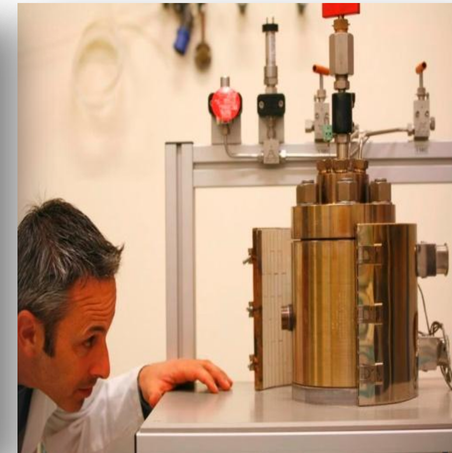
- Implementation of a major safety improvement prgramme:
VD3 and VD4 periodic safety reassessment programmes (PSRs) and post FKH action plan, which will enable to comply with up-to-date safety standards taking into account the lessons learned from Fukushima accident

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**

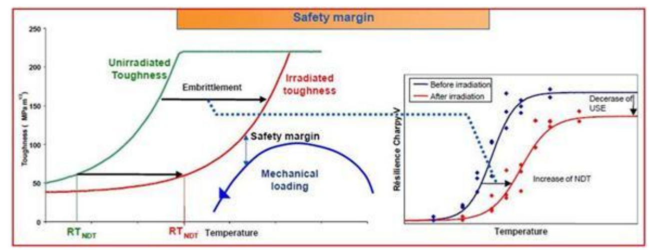
Materials Ageing Institute





11 Members with major utilities (EPRI, REA, Kansai...) representing 66% NPPs worldwide and laboratories

- 80 Researchers and technicians involved
- 20 universities / scientific institutes associated
- 11 M€ annual budget in 2013
- 35 M€ total EDF's Investment (2008-2016)
- 250 participants yearly in the Education and Training program



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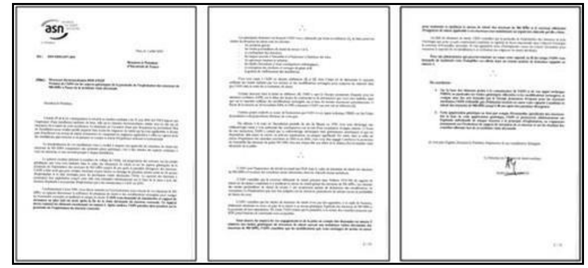


Significant improvements already implemented
during the 2nd and 3rd ten years safety reassessment process

ASN Generic assessment for 900 MW series up to 40 years (2009)

An important programme of maintenance,
refurbishing and replacement of big components is being launched

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

- A sustained R&D effort on long-term behaviour of main components and aging ability,
Creation of Material Ageing Institute at EDF R&D, with major utilities (EPRI, REA, Kansai...), and laboratories

ASN Generic assessment for 1300 MW series up to 40 years (2015)

- ASN generic assessment for 900 MW units in 2009 for operation up to 40 years and approval for first 900 MW plants (FSH 1&2, Bugey 2&4, TRI 1, DAM1..), under some conditions (additional controls, basemat thickening at FSH...);

- ASN generic assessment for 1300 MW units in March 2015 for operation up to 40 years;

=> Taking benefit of the significant investment made in connection with the 3rd ten-year inspections and improvements along with the post-FKH action plan,
EDF objective is to maintain the technical option up to 60 years, with a good level of confidence, under ASN control

Some economic aspects

A 55 MdEu investment from 2014 to 2025, for 58 reactors, with approximately:

- 10 MdEu: post FKH modifications;
- 20 MdEu: other modifications to improve safety (10 years safety reassessment) and regulatory inspections, particularly during ten yearly outages;
- 15 MdEu: component refurbishements or replacements (SGs, condensers, generators, I&C...);
- 10 MdEu: spare parts for routine maintenance, other asset management projects...

Current economical cost for existing fleet (2014 - french high account court), 403,7 TWh over40 years (EU/MWh):

- capital cost (initial investment, future dismantling...) : 22,3;
- O&M (including fuel back end): 28;
- Maintenance and lifetime extension investments: 9,4

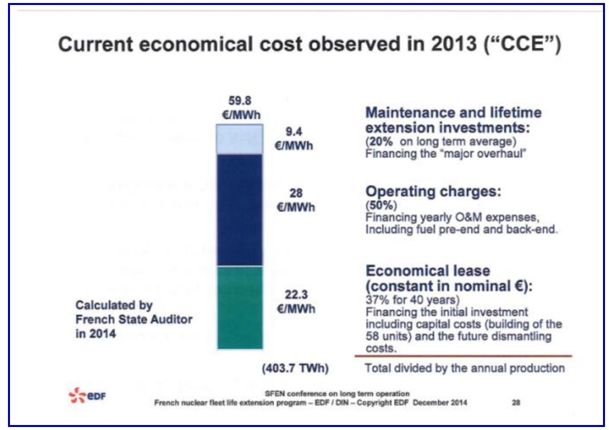
total over 40 years : **59,8 Eu/MWh**

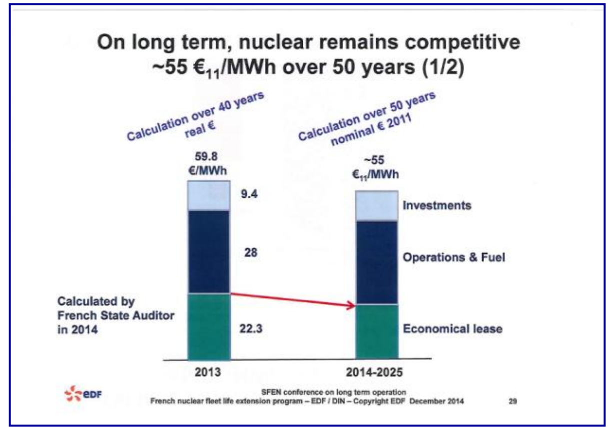
calculation over 50 years: 55 Eu/MWh

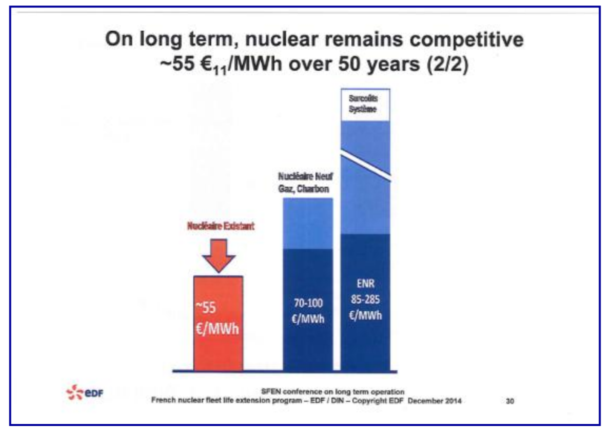
On long term, existing nuclear remains competitive

≈ 55 Eu/MWh (over 50 years)

- NNB, gas, coal: 70 to 100 Eu/MWh
- ENR (buying back tariff): 85 to 285 Eu/MWh (+ system overcost)







Towards LTO: some elements for a conclusion

- Main condition relies in pursuing the day to day operation of NPPs according to the best safety and performance standards;

- Long Term Operation will bring additional value to existing NPPs as a tool to produce safe, reliable, affordable, clean and low carbon electricity, contributing to economy, security of supply, energy independence, environment challenges and skilled industrial employment;

- Under constant requirement of continuous safety improvement and experience feedback, nuclear remains, now and for the future, a major part of the energy mix worldwide, for a competitive and low carbon energy source;

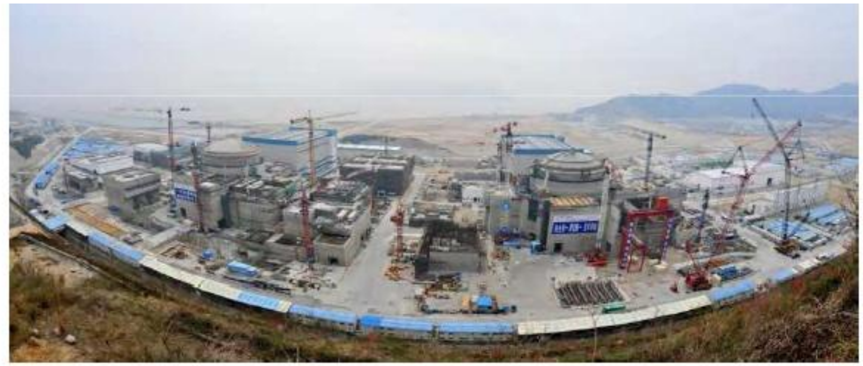
- Science, R&D and international cooperation programme are needed to develop material ageing and physical models to demonstrate the ability to continue operation (nuclear vessel, SSCs, containment, cabling, I&C...)

- Social acceptance and transparency are major points to reach an agreement on the possibility and benefit of LTO, under the control of the independent safety authority;

- LTO is an opportunity for young generation of engineers to develop nuclear science and safety demonstration in order to continue to value existing NPPs, while enabling to give time in order to prepare for the future generation mix and progressive renewal of the existing fleet in the future,

- Developing the skills in engineering, R&D and operation for a safe and reliable nuclear technology is a major condition for this success.

Thank you for your attention and questions...



Reactor pressure vessel & 4 SGs introduced in the reactor building