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Session 1-3 – Utilities:
Modernization of existing nuclear power plants

EDF France modernization program for the existing NPPs

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EDF France modernization program for the existing NPPs

Summary:

Appendix :

1 - French Nuclear Fleet specific context

In operation NPP's	Number of units	Total capacity (GWe)	Average age (years)
PWR 900 MWe 3-Loop	34	30.8	33
PWR 1300 MWe 4-Loop	20	26.4	27
PWR 1450 MWe 4-Loop (N4)	4	6.0	17
Total	58	63,2	28

- **58 reactors in operation**
  - ✓ 19 sites
  - ✓ Capacity : 63,2 GWe
  - ✓ Average age : 28 years
  - ✓ Oldest : Fessenheim 1 (37 years)
  - ✓ Youngest : Civaux 2 (14 years)
- **+ 1 reactor under construction**
  - ✓ FLA 3, 1600 MWE EPR

1 - French Nuclear Fleet specific context

- **The EDF SA modernization program for the existing NPPs fleet is part of the continuous improvement initiative for the EDF fleet and integrates:**

  - **The decennial Periodic Safety Reviews (PSR) process – (VD in French):**
    - ✓ The decennial regulatory safety reassessment process has been implemented since the beginning, enabling to continuously comply with the up-to-date safety standards and the international feedback (TMI 1979, Tchernobyl 1986, Blayais flooding 1999, Heat wave 2003)

  - **The Long Term Operation program (LTO):**
    - ✓ The LTO program aims to operate the existing NPPs fleet well beyond 40 years, in optimal conditions of safety and performance

  - **The post Fukushima Action Plan:**
    - ✓ The post Fukushima action plan is the result of the complementary safety assessment (~ European stress-tests) conducted after Fukushima event

1 - French Nuclear Fleet specific context

- **The EDF modernization program will be monitored through a specific project, the "EDF industrial project" ("Grand Carénage") which:**

  - ✓ integrates all modifications issued from the different programs (PSR, LTO including R&D program, post Fukushima and all other modification or maintenance programs) with a multi-annual vision

  - ✓ assures the monitoring off all aspects of the modernization program: nuclear safety, availability, economic and financial dimension, industrial resources, internal resources and skills, logistic

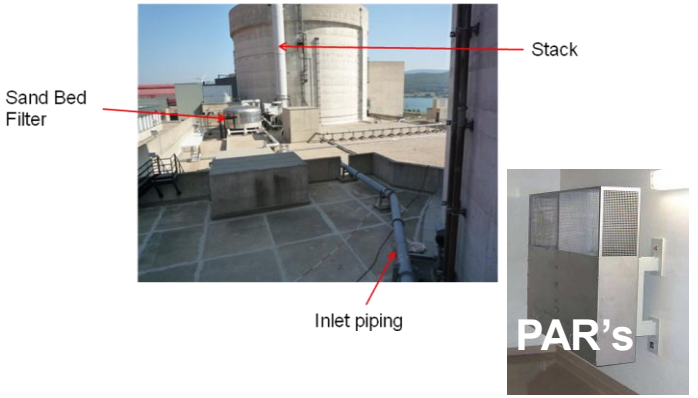
2 - EDF NPP's decennial PSR situation

French ASN allows 10 years operation after each PSR:

	PSR 1 (VD1) (10 years)	PSR 2 (VD2) (20 years)	PSR 3 (VD3) (30 years)	PSR 4 (VD4) (40 years)
900 MW (34 units)	done	done	2009 to 2020 (18 units done)	2019 à 2030
1300 MW (20 units)	done	done	2015 to 2024	2025 to 2034
1450 MW – N4 (4 units)	done	2019 to 2022	2029 à 2032	2039 à 2042

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

- Back-up power supply:
  - 1 steam-driven turbine generator LLS / unit, to resupply essential I&C
  - 1 additional diesel or turbine generator/ site, to resupply one safety train
- Filtered containment venting device (sand bed filter)
- H2 passive recombiners (PARs)
- Flooding protection improvements (after Blayais flooding in 1999)
- Seismic reassessment and protection improvements

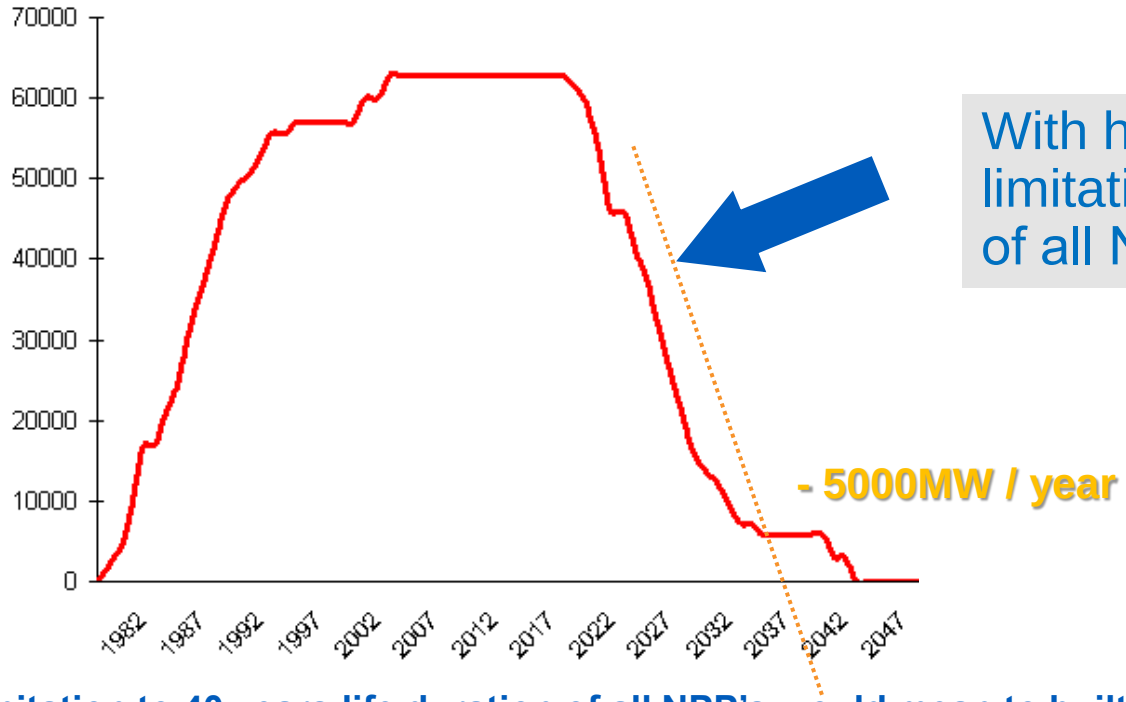


The 900 MWe fleet NPPs will be the first to need the approval of ASN for the step 40 to 50 years (VD4 900 MWe):

- Framing Advisory Group meeting in April 2014 ; French ASN opinion on modifications program expected mid 2016 & approbation for end 2017/mid 2018, deployment start in 2019

3 - EDF LTO program

- **The French NPP's fleet has been built in the years 1980/1990**



With hypothesis of limitation to 40 years of all NPP's

- **The limitation to 40 years life duration of all NPP's would mean to built & start new means of production from 2020 to 2047 equivalent to 30 NPPs of 1500 MWe (at constant installed capacity)**
- **EDF wants to smooth the renewal of the nuclear fleet ➔ life extension from 40 to 60 years is an national issue and a very important objective**

3 - EDF LTO program

To gain the life extension authorization of the existing fleet beyond 40 years, EDF SA has planned:

- **To enhance the safety level of the existing fleet:**
  - **in continuity with the last PSRs and the post Fukushima Complementary Safety Assessment,**
  - **in coherence with the new European WENRA safety reference levels and the next French ASN PSR requirements (for design basis and beyond design)**
  - **and particularly for the next VD4 of the 900 MWe fleet : "take into account as reference the GEN 3 safety objectives, like EPR"**

▶ more details in appendix 1

- **To control the ageing and qualification of the equipment:**
  - **The initial design of the equipment postulated a life duration of 40 years**
  - **Studies and actions have been anticipated to extend up to 60 years:**
    - the demonstration of the resistance of the non-replaceable equipment (vessel, containment)
    - the qualification of the equipment up to 60 years (or to replace it)
- **Performance enhancements:**
  - **To assure an enhanced performance of the NPPs, actions to renew or replace major components, are planned, in connection with industrial capabilities and suppliers:**
    - SG replacement, I&C and MCR modernization, main generator renovation, condenser renovation, main transformers renovation, cooling towers packing replacement, etc

▶ more details in appendix 2

4 - EDF post Fukushima Action plan

Objective: continuous enhancement of the nuclear safety level by deployment of the post Fukushima action plan in 3 phases:

- **by 2015: better protection against total and extended losses of AC power or heat sink (ELAP or/and LHUS) consistent with measures taken by all NPPs Operators in the world:**
  - ✓ implementation of EDF Post Fukushima action plan phase 1:
    use of mobile local and regional equipment and the off-site rescue by the FARN (Nuclear Rapid Response Force)

- **by ~ 2020: significant increase of robustness against extreme natural hazards with additional permanent hardened SSC's:**
  - ✓ implementation of EDF Post Fukushima action plan phase 2:
    1st part of hardened safety core SSC's to provide extended AC power and Water Make-up to all reactors and spent fuel storage pools (1 Ultimate Diesel Generator/unit, Water make-up reserves and distribution, new ECC, etc)

- **by ~ 2030, reach a level of safety close to the best GEN3 reactors, like EPR:**
  - ✓ implementation of EDF Post Fukushima action plan phase 3, in the frame of LTO
    (VD4 900 MWe, VD4 1300 MWe, VD3 N4 series):
    2nd part of hardened safety core SSC's (see next slide)

4 - EDF post Fukushima Action plan

2013 Jan Jun Dec | 2014 Jan Jun Dec | 2015 Jan Jun Dec ---------- 2020 Jan Jun Dec ---------- ~ 2030 Jan Jun Dec

Phase 1: 2012/2015 : Mobile & Temporary Equipment, Emergency Response reinforcement , FARN, 1st modifications

- **1- On site mobile & temporary equipment deployment**
- **2- Plug & Play connections enhancement**
- **3- Emergency Response plan reinforcement (multi units events, diverse communication tools, VSAT, etc)**
- **4- FARN & Off-site mobile equipment (assistance capability)**
  1 unit (end 2012) 4 units (end 2014) 6 units (end 2015)
- **Licensing and implementation of the 1st modifications :**
  Ultimate water supply (1st step)
  Automatic reactor shutdown in case of earthquake (studies)
  Improvement of batteries autonomy

► appendix 3

Deployment in 3 phases

Phase 2 : 2015/2019: Hardened Safety Core deployment (first part)

Licensing process

- **Ultimate Diesel Generator (1/unit)**
- **Ultimate Water supply**
- **New Emergency Control Center (1/site)**
- **Hardened Emergency Response Organization**
- **Spent Fuel Pool levels measurement redundancy**

► appendix 4

Phase 3 : 2019/~2030: Hardened Safety Core completion (linked with LTO)
Draft planning:
EDF proposal to ASN

Licensing process

- **Diverse SG residual heat removal**
- **Ultimate primary circuit injection pump**
- **Extreme Natural hazards protection (end)**
- **Containment residual heat removal**
- **Reactor cavity pit flooding system**

► appendix 5

Appendix 1: EDF nuclear safety goals for the LTO program

❑ 5 fields of studies which could result in modifications:

- **Design Basis Accidents:** reduction of the radiological consequences with the objective to avoid radioactive releases that would require off-site emergency measures

- **Design Extension Condition events:** if CMF more than 10E-7/year, reduction of the risk with specific means (technical, procedure or organization), taking into account EPR approach and post Fukushima modifications

- **Internal hazards (fire, flooding) and external natural hazards:** take into account the new WENRA reference levels for design basis and beyond design basis hazards (beyond design external natural hazards already taken into account in the post Fukushima action plan phases 2 and 3)

- **Severe Accidents:** minimize time and space-related countermeasures in the event of a severe accident, avoiding massive and long lasting radioactive releases (the Post Fukushima action plan phase 3 participate to answer to this objective)

- **Reduction of fuel uncover risk in Spent fuel pools or during handling:** in case of loss of cooling or uncontrolled pool rapid drain (enhancement of the cooling and of the water make-up systems capacities ; reinforcement of the isolation valves to avoid rapid drains ; solutions to reduce the fuel inventory inside the spent fuel pools)

Appendix 2 - EDF LTO program (1/2)

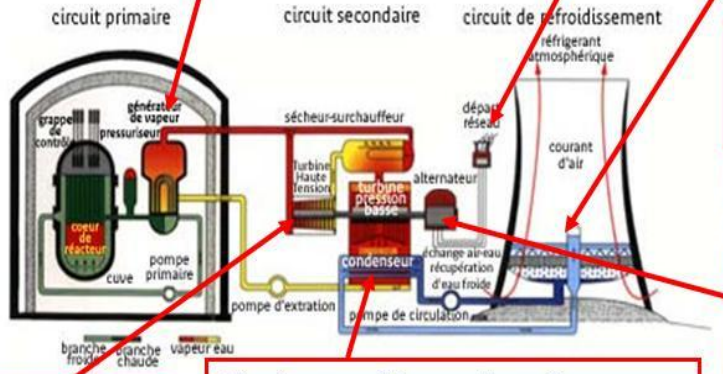
Replaceable components programme

SG Replacement

Replacement of Unit Transformers and Metal-clad Substations

I&C Modernization

Replacement of Cooling Tower Packing



Main Generator
1. Rotor Renovation
2. Stator Replacement

Renovation of Main Turbine LP Cylinders

Condenser : Renovation of
1. Tube Bundles of some units
2. Cleaning System

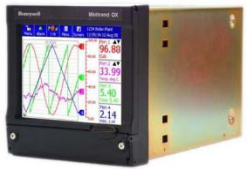
Appendix 2 – EDF LTO program (2/2)

Example of the first NPP modernization modifications planned in the frame of the EDF industrial project

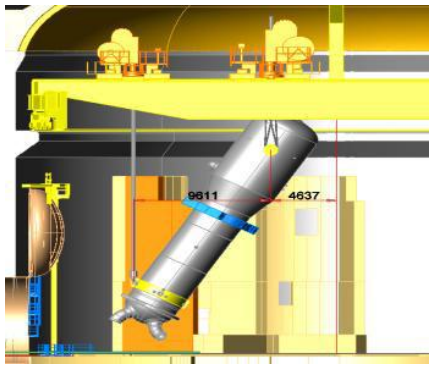
✓ **Paluel 2 NPP (1300 MWe) in April 2015, during VD3 outage (215 days)**

About 110 modifications including:

- I&C and main control room modernization



- Steam Generators replacement
- Main transformer replacement
- Raw-water filter drum & essential service water piping replacements
- Condenser re-tubing



✓ **Completion of the Paluel 2 modernization program from 2016 and above**

(including completion of post Fukushima phase 2 and 3 modifications)

Appendix 3 - EDF post Fukushima action plan
Phase 1 Progress (2012-2015) (1/3)

Objective: ***Increased protection against total loss AC-power or Heat-sink, using mobile and temporary equipment***

1. 0n-site mobile equipment deployment: end 2014

- Water pumps, diesel generators, air compressors, all logistic to allow a minimum on-site autonomy of 24 h



Temporary DG to resupply I&C and control room, mobile water injection pump and air compressor

Batteries for RCS relief valves

Temporary light structure for mobile on-site equipment storage

2. Plug and Play connection points enhancement: mid 2015

- Facilitating on-site and FARN mobile equipment connection in extreme conditions

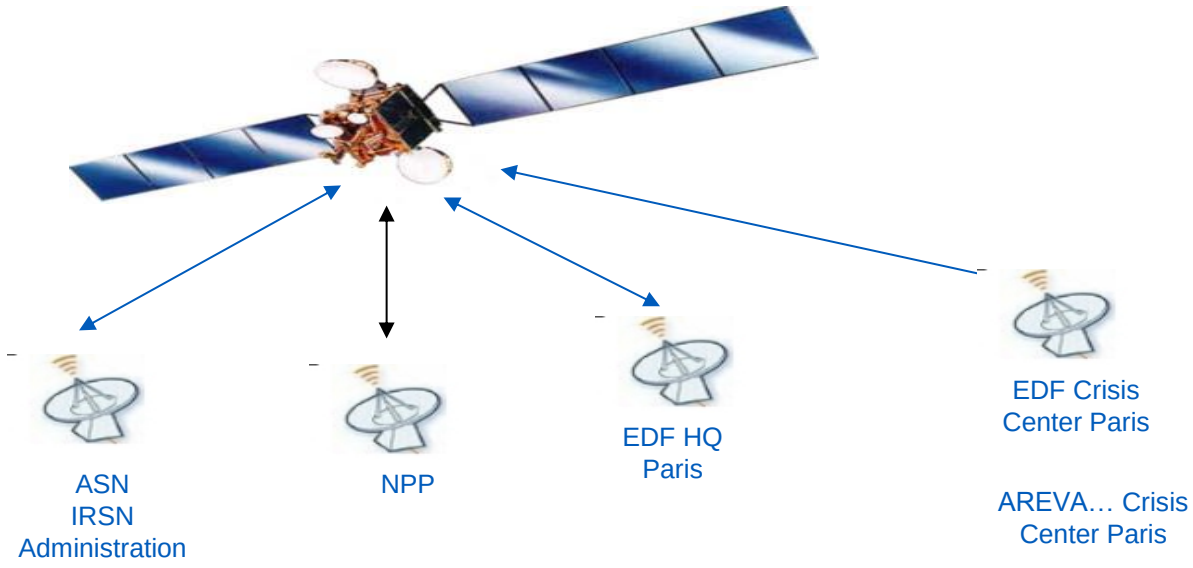


Appendix 3 - EDF post Fukushima action plan
Phase 1 Progress (2012-2015) (2/3)

3. Emergency Response plan reinforcement:

- Emergency Response plan taking into account FARN & multi-units events: **end 2014**

- Emergency telecommunications:
  - ✓ 1 autonomous satellite GSM in each unit: **06/2012**
  - ✓ 1 fixed VSAT com. / Emergency center
    1 mobile VSAT com. / FARN center : **2012 to 2015**



Appendix 3 - EDF post Fukushima action plan
Phase 1 Progress (2012-2015) (3/3)

4. FARN deployment (Nuclear Rapid Response Force):

- Mobile off site equipment for air, electricity and water resupply + all logistic
- Off-site human resources rescue
- FARN on site in less than 12h and fully operational in less than 24h after alert

~ 310 people, dispatched in:

- 1 national headquarter (30 people) in Paris
- 4 regional centers (70 people : 5 teams of 14 p) : Civaux, Bugey, Dampierre, Paluel
- 

Assistance capability (ASN requirements):

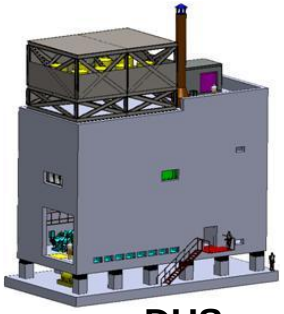
- ✓ 4 units (end 2014)
- ✓ 6 units (end 2015)

Appendix 4 - EDF post Fukushima action plan Phase 2 program (2015-2020) (1/3)

Objective: significant increase of robustness against extreme hazards:

➢ **Additional hardened AC-power and Water supplies, to all reactors and Spent Fuel Pools (1st systems of the Hardened Safety Core SSC's):**

- 1 Ultimate back-up Diesel "DUS" / unit
- 1 Ultimate water supply system (groundwater/reservoirs/basins)
- 1 new on-site Emergency Control Center
- Flooding protection enhancements
- Passive tight seals for primary Main Coolant Pumps
- Spent Fuel Pools level measurements redundancy
- Existing FCV reinforcement against earthquake (sand-bed filter)
- Basic Sumps (sodium tetra-borate baskets inside containment)
- Reinforcement of the Emergency Response Organization (on-site management prior to FARN rescue)



DUS

Ultimate water supply from groundwater

New bunkerized On-site Emergency Control Centre

Existing FCV reinforcement

Ultimate water supply from reservoir

Appendix 4 - EDF post Fukushima action plan Phase 2 program (2015-2020) (2/3)

Example : New on-site Emergency Control Centre

Deployment: from 2014 to 2019, one on each site:

- Hardened building and facilities, including communication tools
- Plant Data supervision room with essential data
- Emergency tools and on-site mobile equipment storage
- Intervention facilities (preparation and documentation rooms, hot and cold control and dressing rooms)
- Living conditions (rest, feeding, hygiene)

Main technical specifications:

- Total surface: 2200 m², 3 floors (2+1)
- Capacity : 100 people (x2 during shift turn-over)
- Same building for all sites (19 sites)
- Radiation and contamination protections , HVAC (2 trains)
- Autonomy 72h (one specific EDG + fuel tank)

Resisting to “hardened” natural hazards:

- Hardened flooding and earthquake
- Explosion : 10kPa in 15 ms (like the French EPR)
- Tornado : F4, Lightning : 300 kA
- Climatic conditions : -16°C in winter; +36 °C in summer
- Wind, snow, accidental rain, hailstorm
- Industrial risk : fire, chemical aggression...

The first ECC building is under erection at Flamanville NPP (2014/2016)

(2 x 1300 MW units and 1 EPR)

Appendix 4 - EDF post Fukushima action plan
Phase 2 program (2015-2020) (3/3)

Erection of the new Emergency Control Centre in the Flamanville NPP (Nov. 2014)

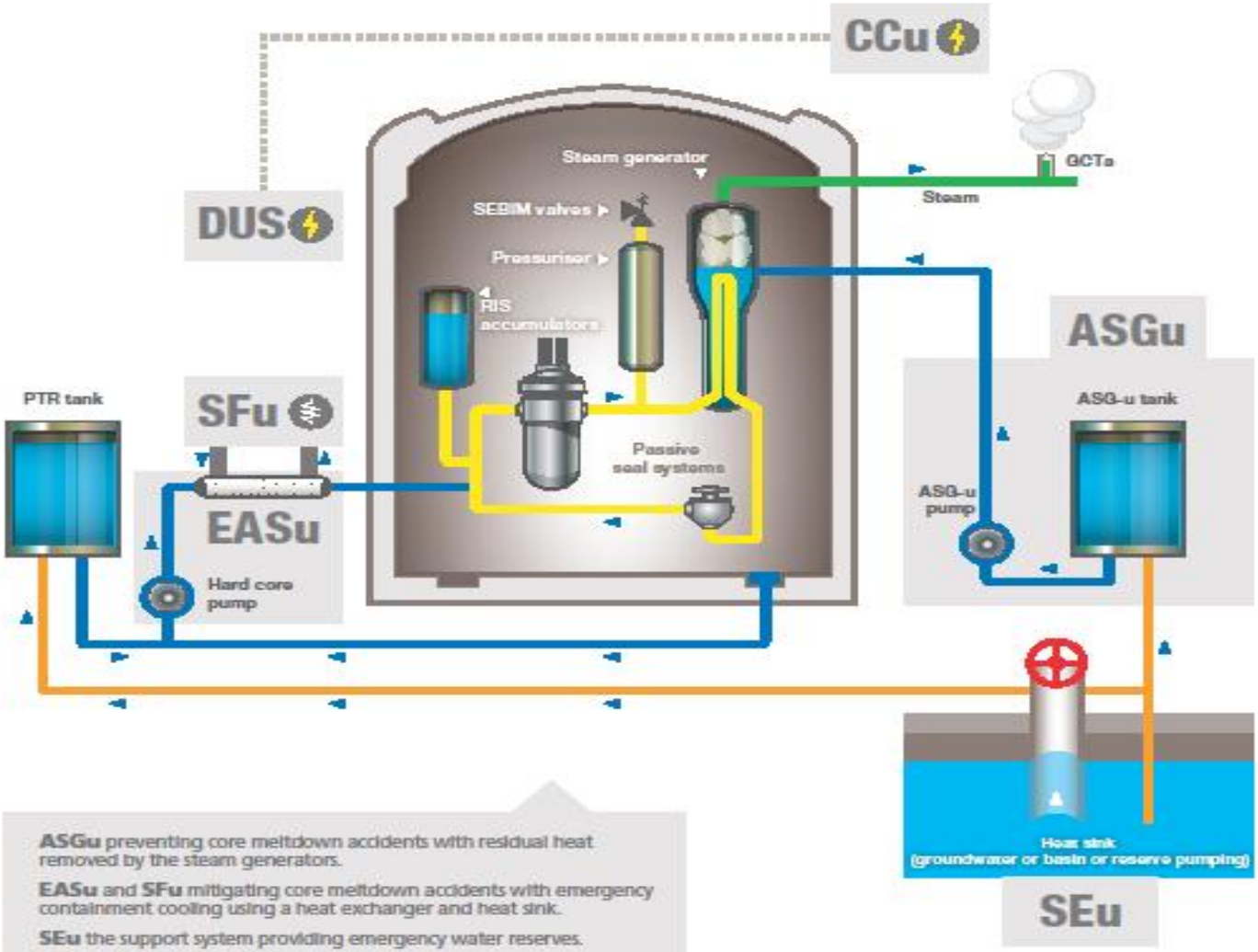
Appendix 5 - EDF post Fukushima action plan Phase 3 program (2019-2030) (1/2)

Objective: reach a level of safety close to best GEN 3 reactors, like EPR

➢ Completion of the Hardened Safety Core, taking into account the new requirements of the French ASN (resolution letters of the 21st January, 2014), as part of the LTO program

- One diverse SG residual heat removal system (Ultimate EFWS: dedicated feed water pump, dedicated water tank and steam relief valves)
- One dedicated Ultimate injection pump to the primary circuit
- One Containment residual heat removal system
- One Reactor cavity pit flooding system
- Earthquake and flood protection reinforcement s if needed (HSC criteria)

Appendix 5 - EDF post Fukushima action plan
Phase 3 program (2019-2030) (2/2)



Example of reactor building hardened core systems