Post Fukushima assessment and follow up

French National Action Plant

Nuclear Facilities

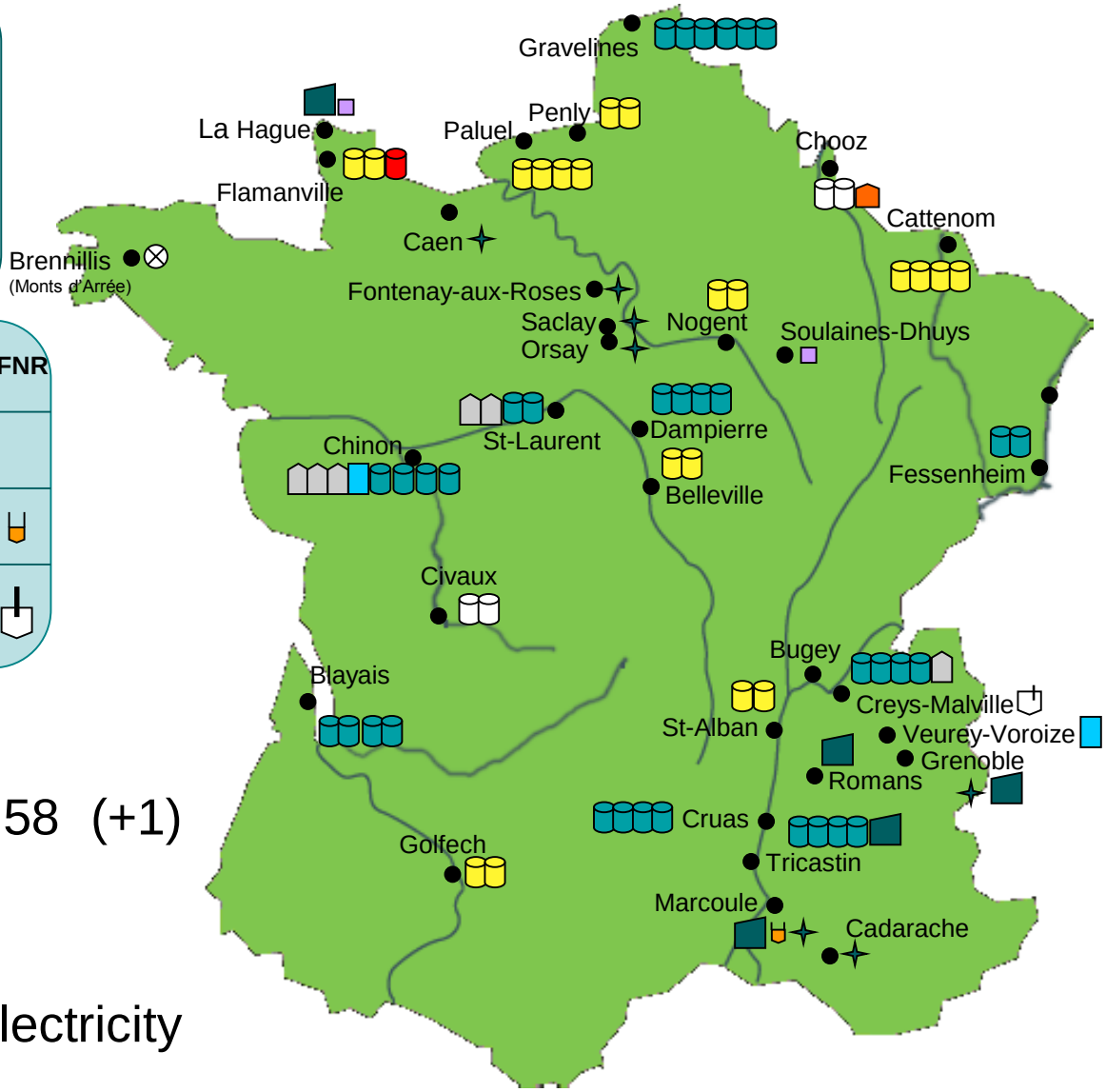
Fuel cycle
(enrichment, fabrication, retreatment)

Waste disposal sites

Research centers

Laboratories

58 + 1PWR					Graphite Gaz	Gaz Eau lourde	1 FNR
300 MWe	900 MWe	1300 MWe	1450 MWe	1600 MWe			



NPPs:

- Standardized fleet of 58 (+1) PWR
- 1 operator
- 80% of the French electricity production

French implementation of the Stress tests: the Complementary Safety Assessments (CSA)

INTRODUCTION

"stress test" analysis of the safety of nuclear facilities

- complies with the request from the Prime Minister (23rd March 2011) and with the European Council conclusions (24th and 25th March 2011)
- is a complementary safety assessment, a complementary approach to the continuous improvement process of safety pursuant to the law and overseen by ASN (periodic safety reviews and integration of operating experience feedback)
- concerns 150 nuclear installations (58 NPP, 1 NPP under construction, fuel cycle facilities, research reactors, etc.)
- covers:
  - extreme natural events (earthquake, flooding)
  - loss of the ultimate heat sink or loss of electrical power
  - severe accident management
- addresses also Human and Organizational Factors + subcontractors issue

French implementation of the Stress tests: the Complementary Safety Assessments (CSA)

3 topics

- **Hazards**
- **Loss of functions**
- **Severe accident management**

- Robustness to natural hazards

(earthquake/flooding)

- Robustness to loss of electrical power supplies and cooling systems

- Robustness of licensee's accident management organization and measures

"Real" status

Possible configurations

Pool/ reactors

Site consideration

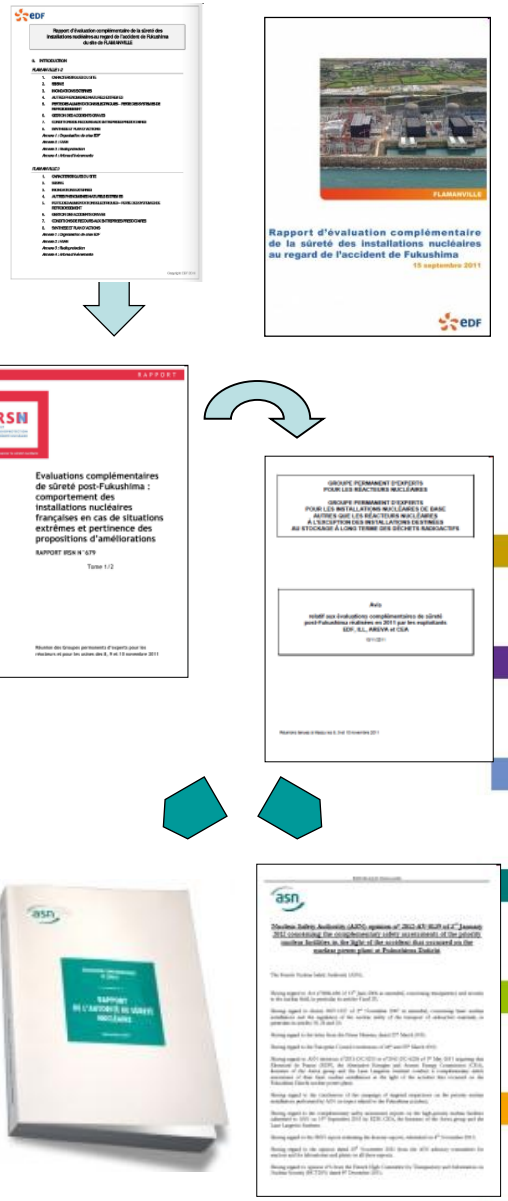
Other BNI consideration

A graded approach

Engineering evaluation

French implementation of the Stress tests: the Complementary Safety Assessments (CSA)

- 5th May 2011: **ASN Resolutions** requiring licensees to perform the "stress tests" in accordance with precise specifications
  - Based on work done at EU level (WENRA and ENSREG) from March to May
- 15th Sept. 2011: **licensees' reports submitted**
- Sept.-Dec. 2011: **technical analysis**
  - **IRSN expert report**
  - Advisory committees opinions
  - Contributions of many stakeholders
- 3rd Jan. 2012: **ASN position and report**
- June 2012: **ASN resolutions** requiring the licensees to implement measures to strengthen safety



French implementation of the Stress tests: the Complementary Safety Assessments (CSA)

Resolutions adopted by ASN on June 26, 2012, setting some thirty complementary <u>requirements</u> (legally binding)

- To reinforce the safety margins beyond design-basis level earthquake and flooding
- Decision to implement **new and robust safety measures** rather than performing sophisticated analysis
- Deadlines from 2012 up to 2018 ➔ ***implementation of the safety improvements as soon as possible, not waiting for the next PSRs***
- The requirements of ASN following the stress tests imply **considerable work**

- **Resolution adopted by ASN on January 21, 2014 setting requirements for the hardened safety core design.**

French Complementary Safety Assessments main conclusions

- ASN's position : ***«the facilities examined offer a safety level that is sufficient for ASN not to request the immediate shutdown of any of them […]. At the same time, ASN considers that continued operation of the facilities requires that their robustness to extreme situations be increased beyond the existing safety margins, as soon as possible.»***

- CSA are complementary to the continuous improvement of safety process provided for by the law (periodic safety reviews and integration of operating experience feedback).

French Complementary Safety Assessments main conclusions

- **Social Organisational and Human Factors are essential aspects of nuclear safety**

➢ 3 priorities:
  – renewal of the licensee workforces and skills
  – Organisation of the use of subcontracting, including subcontractor contribution to accident management
  – Research on these topics

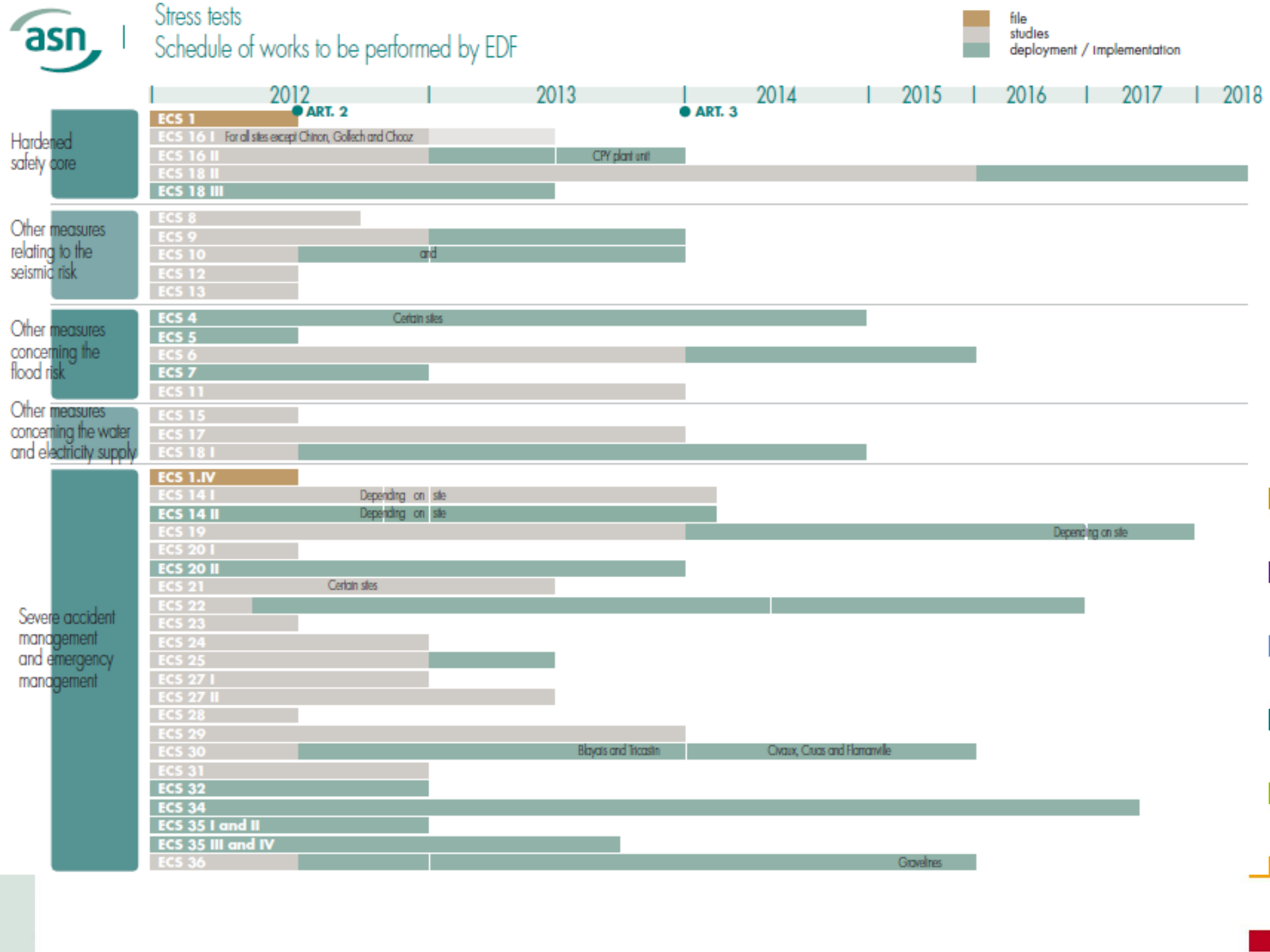
➢ ASN set up a working group on these subjects, including the licensees, the trades unions, the HCTISN, the Ministry for Labour, the Ministries responsible for nuclear safety and IRSN.

French Complementary Safety Assessments main conclusions

- The licensees will be required to **strengthen the nonconformity processing system:**
  - The nonconformities identified during the CSAs do not directly compromise the safety of the facilities concerned but they can, in particular if combined, constitute factors such as to weaken the facilities.

- On the basis of the in-depth experience feedback from the Fukushima accident, ASN will **reinforce the regulatory requirements** for the nuclear facilities, particularly with respect to earthquakes, flooding and risks associated with other industrial activities.

Stress tests
Schedule of works to be performed by EDF



asn | Stress tests
licensee: EDF

Hardened safety core
Earthquake
Flooding
Water and electricity supplies
Severe accident management and emergency management

Art.2 :	Implementation schedule for all the measures
Art.3 :	Interim assessment of lessons learned from the accident
ECS - 1:	Defining the structures and components of the "hardened safety core", including the emergency management premises Defining the requirements applicable to this hardened safety core Hardened safety core based on diversified structures and components
ECS - 4:	End of the Blayais experience feedback (REX) work
ECS - 5:	Conformity of the volumetric protection
ECS - 6:	Reinforcement of protection against flooding, above the current safety baseline
ECS - 7:	Measures to cope with site isolation in the event of flooding (Cruas, Tricastin)
ECS - 8:	Conformity of seismic instrumentation with RFS1.3.b
ECS - 9:	Reinforcement of the seismic interaction approach
ECS - 10:	Reinforcement of team preparation in the event of an earthquake
ECS - 11:	Robustness of the Fessenheim and Tricastin embankments
ECS - 12:	Verification of the seismic design basis of the fire-fighting system
ECS - 13:	Study of the implementation of automatic shutdown in the event of an earthquake
ECS - 14.I:	Integration of industrial risks in extreme situations
ECS - 14.II:	Coordination with neighbouring industrial operators in the event of an emergency
ECS - 15:	Heat sink design review
ECS - 16.I:	Emergency water make up system
ECS - 16.II:	Emergency water make-up in the reactor coolant system, for shutdown states
ECS - 17:	Reinforcement of the facilities to manage long lasting situations of total loss of heat sink or total loss of electrical power supplies
ECS - 18.I:	Reinforcement of battery autonomy
ECS - 18.II:	Ultimate backup diesel generator sets
ECS - 18.III:	Installation of provisional emergency generator sets
ECS - 19:	Redundancy of instrumentation for detecting reactor vessel melt-through and hydrogen in containment
ECS - 20:	Reinforcement of pool condition instrumentation
ECS - 21:	Additional measures to prevent or mitigate the consequences of a fuel transport package falling in the fuel building Studies of the consequences of a package falling in the fuel building
ECS - 22:	Reinforcement of the measures to prevent accidental rapid draining of the pools
ECS - 23:	Placing a fuel assembly in safe position during handling
ECS - 24:	Thermohydraulic development of a pool accident
ECS - 25:	Reinforcement of the provisions for managing a transfer tube leak
ECS - 27.I:	Study of the feasibility of installing a geotechnical containment or a system with the same effect
ECS - 27.II:	Updating of the hydrogeological sheets
ECS - 28:	EPR - Reinforcement of the provisions for managing the pressure in the containment
ECS - 29:	Reinforcement of the U5 venting-filtration system ("sand-bed filter")
ECS - 30:	Designing the emergency premises to withstand earthquakes and flooding
ECS - 31:	Modifications to ensure facility management further to releases
ECS - 32:	Multiple plant unit emergency organisation
ECS - 34:	Updating of agreements with hospitals
ECS - 35. I and II:	Feasibility of emergency management actions in extreme situations
ECS - 35. III and IV:	Accident management training
ECS - 36:	FARN (Nuclear rapid intervention force)

French action plan.

Enforceable by ASN decision (legally binding).

French Complementary Safety Assessments main conclusions

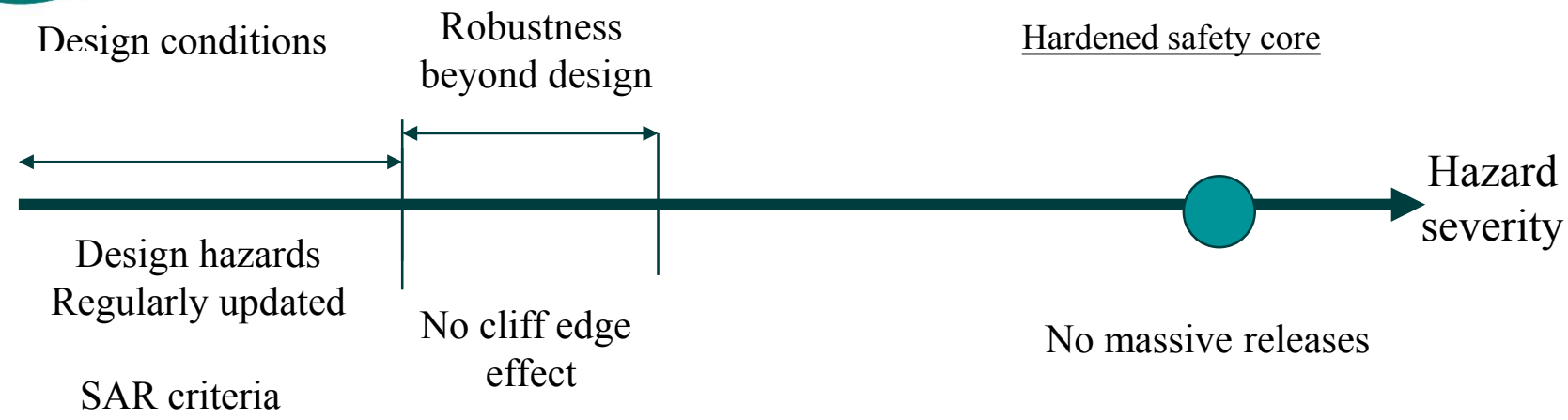
- **Hardened safety core** of material and organisational measures to allow control of the basic safety functions in extreme situations

- "**Nuclear rapid response force** (FARN)" concerning EDF
  - gradual creation from 2012 to 2014 of the national response system proposed by EDF
  - specialist crews and equipment, able to take over from the personnel on a site affected by an accident and to deploy additional emergency response resources in less than 24 hours.
  - forward, capacity for simultaneous intervention on all the reactors of a site.

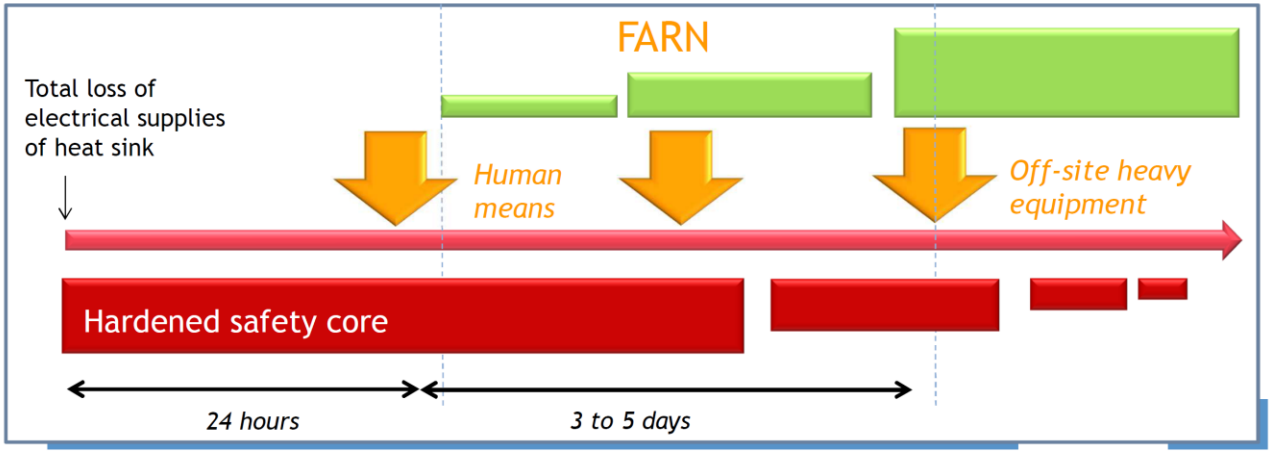
- Implement an emergency management centre designed for site accidents

- Reinforced measures to insure water make-up and residual heat removal from **the spent fuel pools**

Hardened safety core
ASN requirements



- Natural hazards shall not lead to accident sequences
- Beyond design natural hazards should not lead to a cliff edge effect in terms of releases in the environment



Hardened safety core

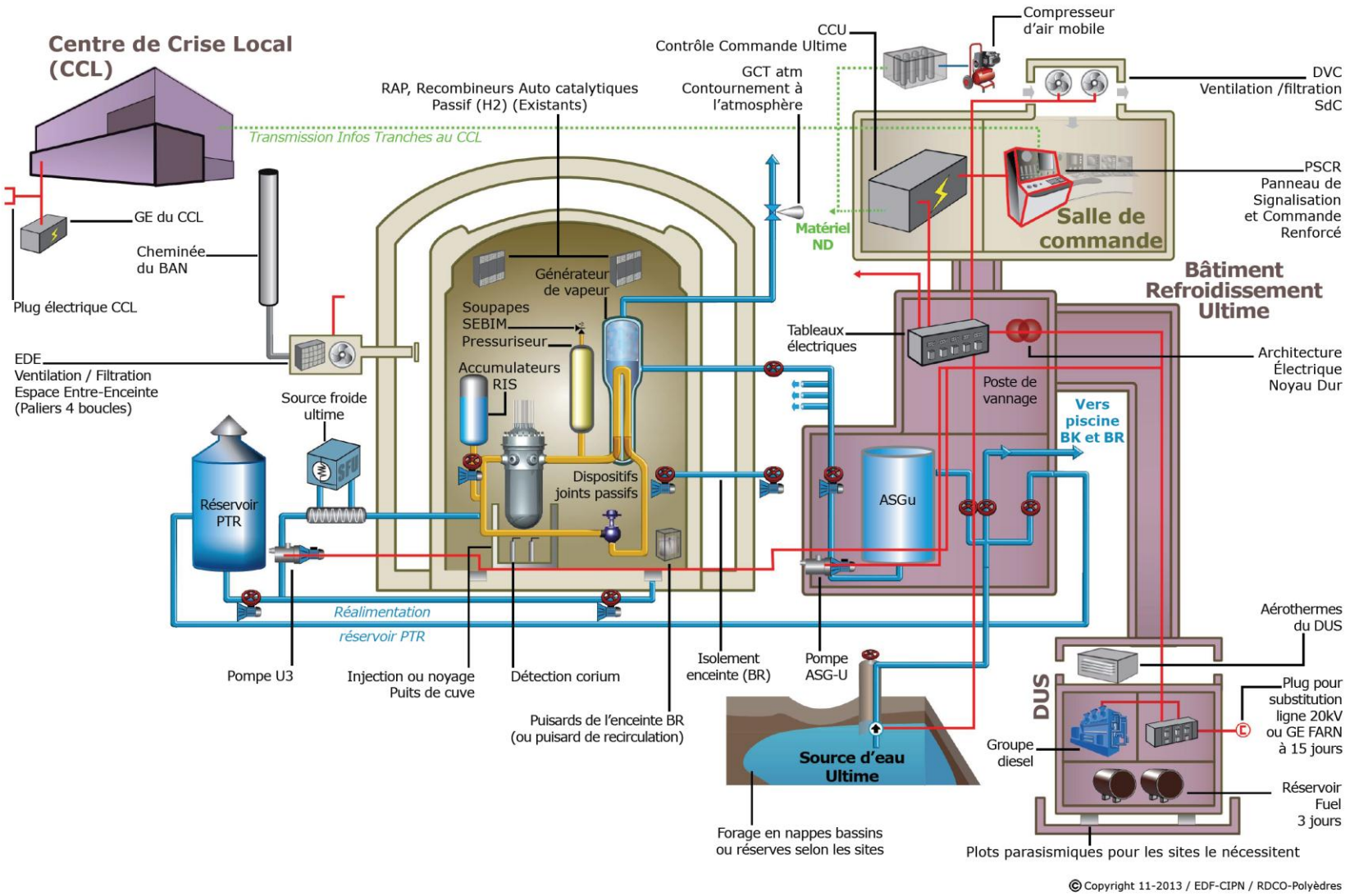
ASN requirements in order to increase robustness

- **ASN Requirement ECS-1:** “hardened safety core” (beyond design),
  - 3 objectives, for the situations studied in the stress tests
    - prevent or mitigate the progress of an accident with fuel melt,
    - mitigate large-scale radioactive releases,
    - enable the licensee to perform its emergency management duties.
  - strengthened equipment including
    - an **additional ultimate electricity generating set** for each reactor;
    - an **diverse emergency cool-down water supply** for each reactor;
    - **new crisis management premises**, offering greater resistance to hazards and remaining accessible and habitable at all times and during long-duration emergencies
    - **mobile devices** and **means of communication** essential to emergency management
    - technical and environmental **instrumentation**
  - Systems structures and components (SSC) included in the hardened safety core shall be maintained in a **functional state, in particular for the extreme situations studied in the stress tests**. SSCs shall be designed with significant fixed margins in relation to the requirements currently applicable.
  - Composed of **independent and diversified SSCs** in relation to the existing ones to avoid core cooling failure. The licensee shall justify the use of undiversified or existing SSCs.

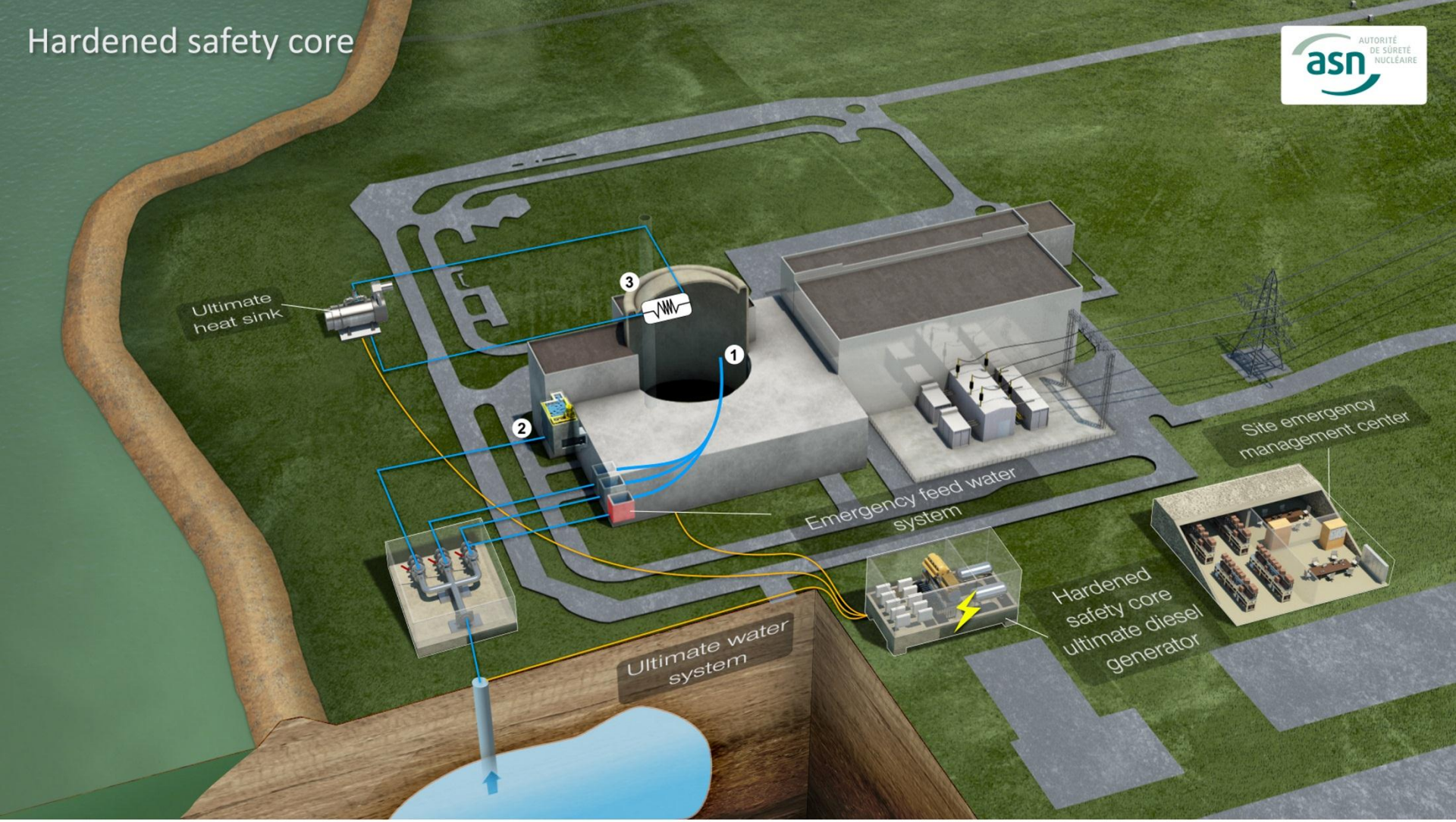
Design requirements for the hardened safety core. January 21th 2014 ASN resolutions

- additional safety goals to the hardened safety core
- define requirements to the hardened safety core instrumentation
- define design requirements to the I&C and electrical distribution
- Set requirements for SSCs and connection points for mobiles means
- Update flooding reference level where needed
- Define an increased seismic level for the hardened safety core (including probabilistic definition)
- Set demands for external hazards other than seismic or flooding
- Set design rules for new SSCs
- Set conditions for the mission duration of the new hardened safety core SSC to take into account time dependant failure mode.

NOYAU DUR REACTEUR



Hardened safety core



January 2014

1 : reactor cooling system
2 : fuel pool cooling system
3 : reactor containment cooling system

ASN resolution June 2012
General « post-Fukushima » approach : 3 phases deployment for the fleet (1/2)

- **Phase 1 : short term covering** by crisis means and interim solutions for beyond design SBO and LHS (several units, long duration)
  - Crisis management, local and regional crisis resources,
  - Multi units and long duration crisis : organization, local resources and mobile safety resources, telecommunication functions, …
  - Interim diesels and pumps, interim ultimate water make-up system…
  - “plug and play” connections for primary and secondary water make-up
  - Deployment of FARN
  - Measures largely consistent with international safety measures (mobile resources, like US FLEX-Flexible Response Capability)…

- **Phase 2** : **Mid term covering** by definitive SSC for beyond design SBO and LHS situations
  - Improvement in the robustness of the main safety systems, beyond the current safety requirements, to better prevent SBO and LHS
  - Deployment of the “**hardened safety core**” main SSCs, with a strengthened robustness against external events, e.g.:
    - ultimate back-up diesel generator (DUS),
    - ultimate water make-up system,
    - new ECC, …

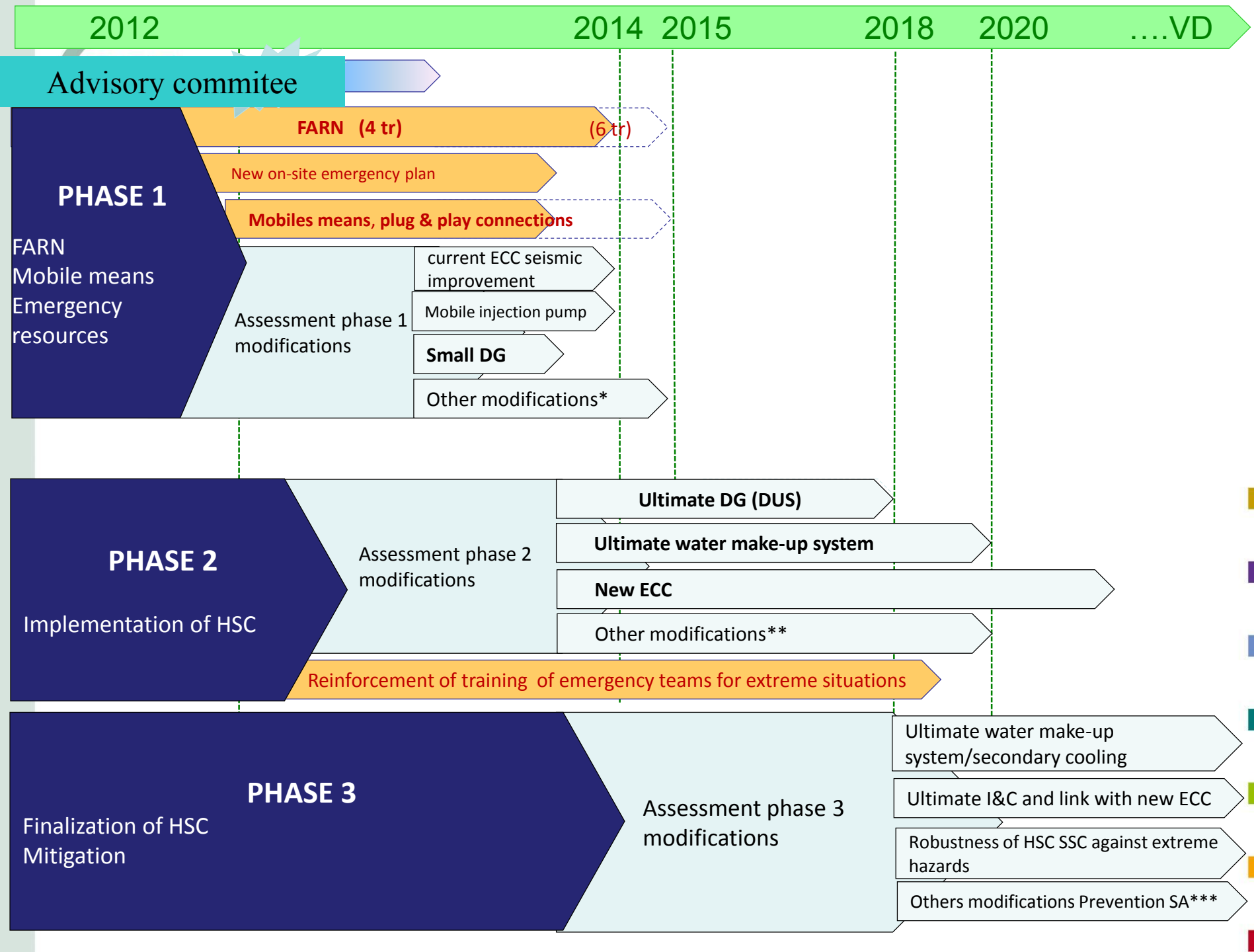
ASN resolution June 2012

General « post-Fukushima » approach : 3 phases deployment for the fleet (2/2)

The first two phases enable a significant safety benefit, by already managing extreme situations beyond the framework of the referential, directly induced by the lessons of Fukushima

Phase 3 : Long term covering : ultimate hardened safety core preventing, in most extreme deterministic and beyond design situations, large and long-lasting radioactive releases in the environment

- Complete deployment of the hardened safety core SSCs starting in 2019
- Severe accidents primary injection pump, improved “feed and bleed” design, improved reactor containment cooling system (that does not require opening of the containment venting-filtration system)…
- Safety reassessments taking into account FKA feedback of experience


2012
2014
2015
2018
2020
….VD
Advisory commitee
FARN (4 tr)
(6 tr)
New on-site emergency plan
Mobiles means, plug & play connections
PHASE 1
FARN
Mobile means
Emergency resources
Assessment phase 1 modifications
current ECC seismic improvement
Mobile injection pump
Small DG
Other modifications*
PHASE 2
Implementation of HSC
Assessment phase 2 modifications
Ultimate DG (DUS)
Ultimate water make-up system
New ECC
Other modifications**
Reinforcement of training of emergency teams for extreme situations
PHASE 3
Finalization of HSC
Mitigation
Assessment phase 3 modifications
Ultimate water make-up system/secondary cooling
Ultimate I&C and link with new ECC
Robustness of HSC SSC against extreme hazards
Others modifications Prevention SA***

Action plan

Phase 1 (2012-2015):

- temporary or mobile measures against total loss of the heat sink or SBO
- reinforcing of the existing on-site emergency equipment (pumps, generator sets, etc.),
- installation of medium-capacity ultimate backup diesel-generator sets,
- reinforcing of the earthquake resistance (SSE) and flood resistance (maximum thousand year flood) of the emergency management premises,
- installation of tappings for connecting mobile equipment, particularly FARN's equipment,
- deployment of the FARN (it is already capable of intervening on a 4 plant-unit site, and by the end of 2015 it will have a 6 plant-unit intervention capability),
- implementation of an automatic reactor trip in the event of an earthquake (end of implementation 2016)
- installation of electrically backed-up level measurement instrumentation in the pools.

Status

Phase 1 actions are on time except :

implementation of an automatic reactor trip in the event of an earthquake : end of implementation for the whole NPP fleet delayed to end 2016.

ASN position :

As severe accident measure have already been implemented during previous PSR, end of phase 1 will provide safety improvements that respond to peer review findings that require effective short term reinforcements

Action plan

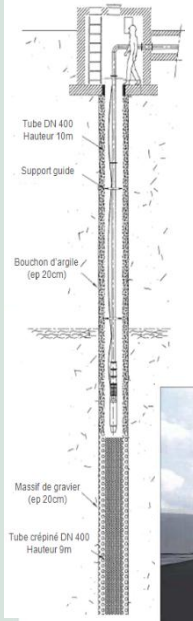
Phase 2 (2015-2020):

- large-capacity ultimate backup diesel-generator, including dedicated building to house it,
- dedicated ultimate water source,
- ultimate water makeup source for each reactor (on the PTR[1] reservoir and the steam generator auxiliary feedwater supply systems) and each pool,
- reinforcing of the earthquake resistance of the containment venting filter,
- installation of sodium tetraborate baskets to reduce the emission of gaseous iodine in a severe accident situation on reactors that do not have SIC (silver-indium-cadmium alloy) control rod clusters,
- installation of the first protections against extreme flooding (high-intensity rainfall and earthquake-induced rupture of tanks) in addition to the existing protected volume measures,
- implementation of means for detecting reactor vessel melt-through or the presence of hydrogen in the containment
- installation of passive tightness systems for the seals of the reactor coolant motor-pumps,
- devices to prevent, in the event of a break in the transfer tube or the pool compartment drainage pipes, exposure of the fuel assemblies during handling and enable them to be placed in a safe position using the emergency manual controls,
- reinforcing of the operating teams to be capable of managing all the extreme situations studied in the stress tests,
- construction on each site of an emergency centre capable of withstanding extreme external hazards (functionally independent in an emergency situation).

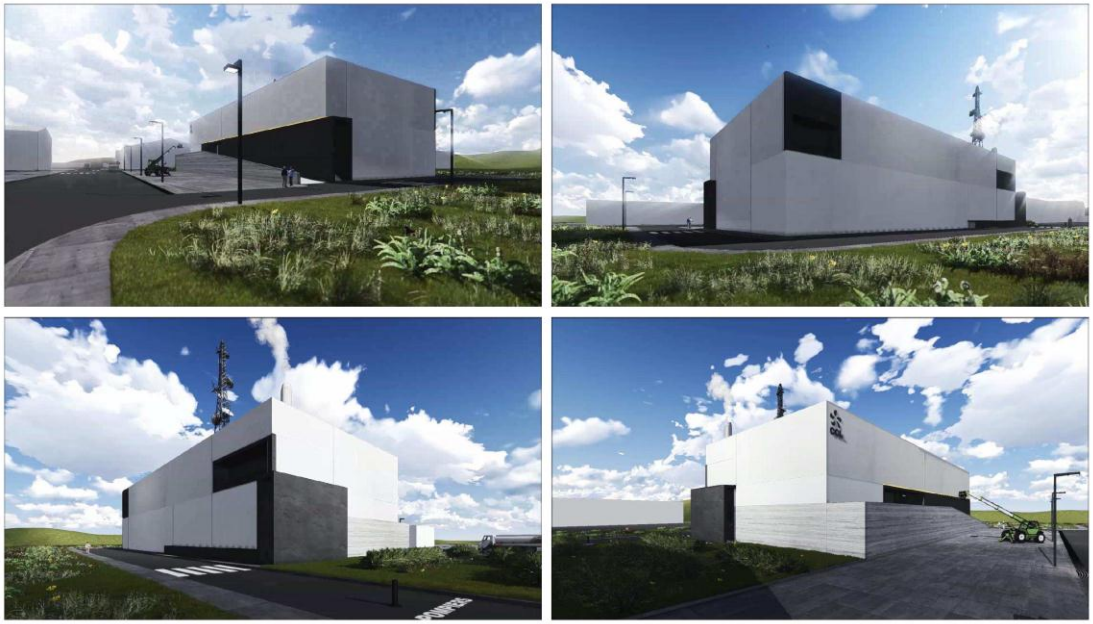
[1] PTR: three-letter code for "Reactor cavity and spent fuel pool cooling and treatment system"

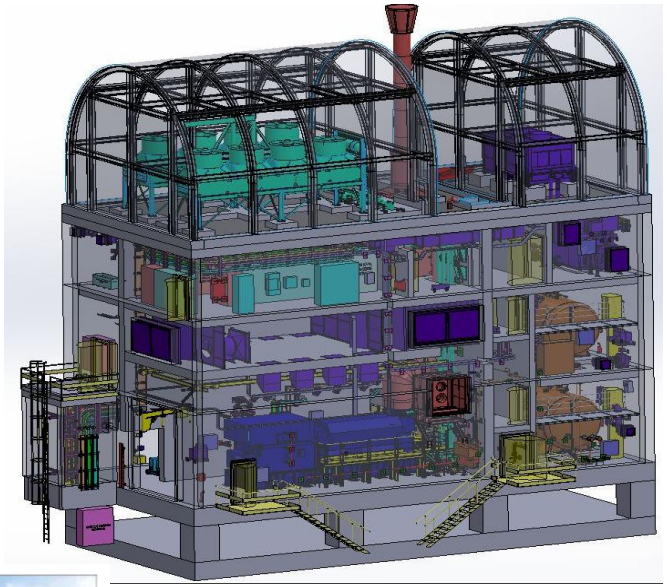
Phase 2, main systems

ultimate water makeup source



Site emergency centre

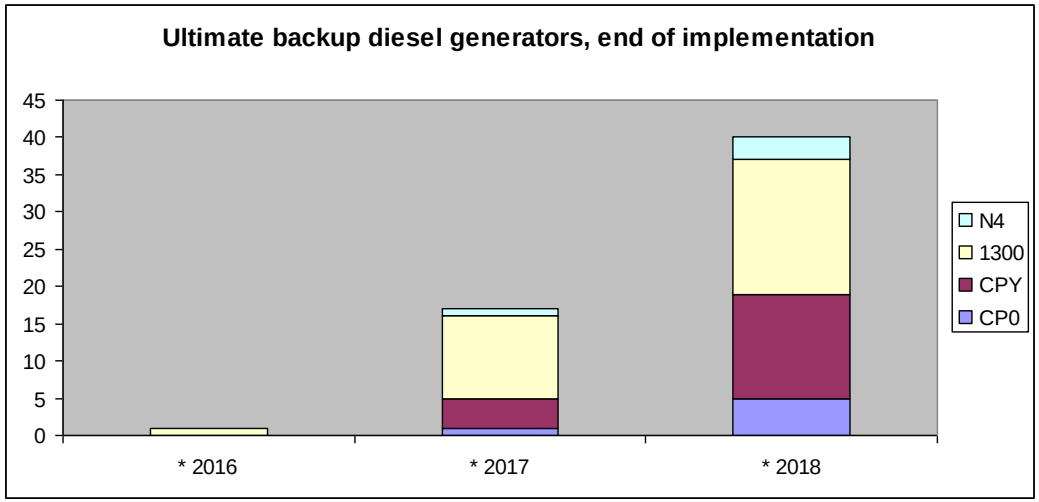


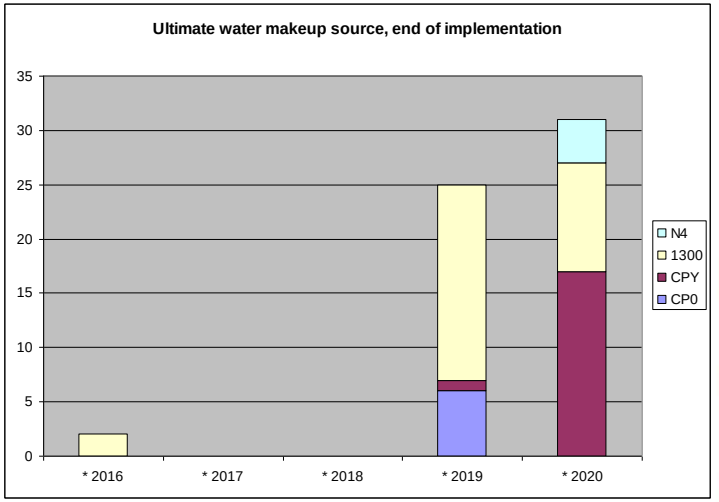


large-capacity ultimate backup diesel-generator set, including dedicated building to house it

Phase 2

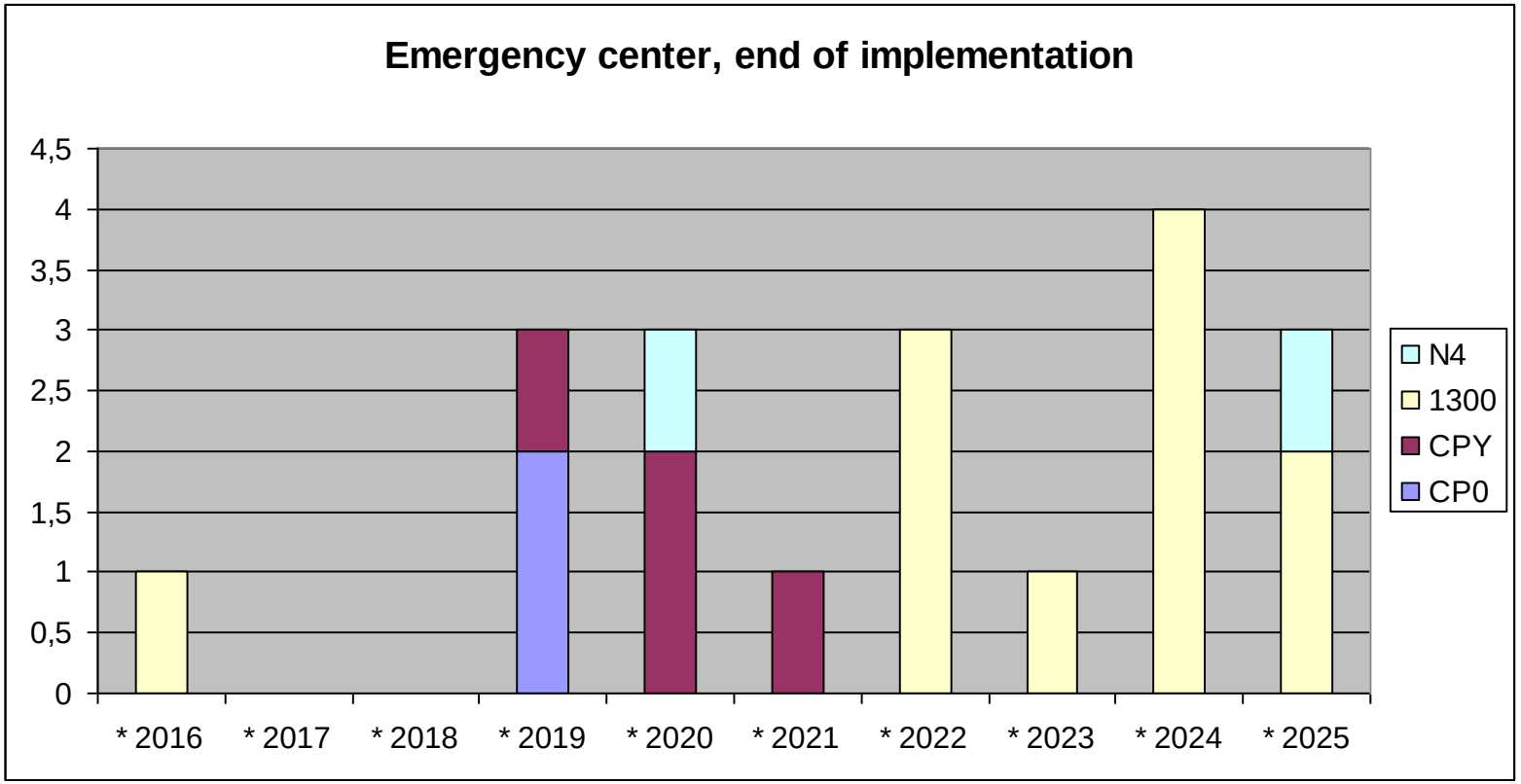
Status: Projected schedule on time





Except…

Phase 2



- Emergency centre implementation time frame will be examined by ASN

Phase 3

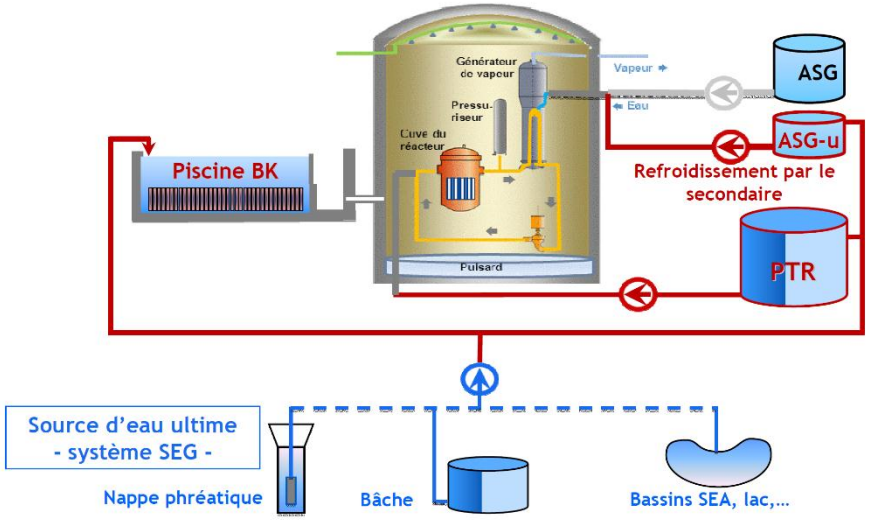
Phase 3 (first implementation 2019):

- removal of the residual power by the steam generators by means of an independent ultimate backup feedwater system supplied by the ultimate heat sink,
- addition of a new makeup pump to the primary system,
- finalisation of the ultimate makeup connections - through fixed circuits - to the steam generator auxiliary feedwater supply system, to the PTR tank and to the spent fuel pool,
- installation of an ultimate instrumentation & control system and the definitive instrumentation of the hardened safety core,
- installation of a reactor containment ultimate cooling system (that does not require opening of the containment venting-filtration system),
- implementation of a solution for flooding the reactor pit to prevent corium melt-through of the basemat.

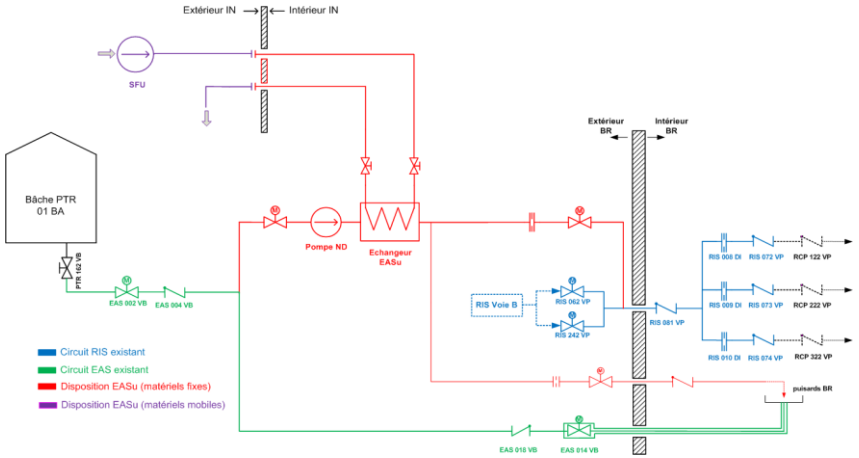
  (EDF still has to conduct feasibility studies on these last two points).

Phase 3

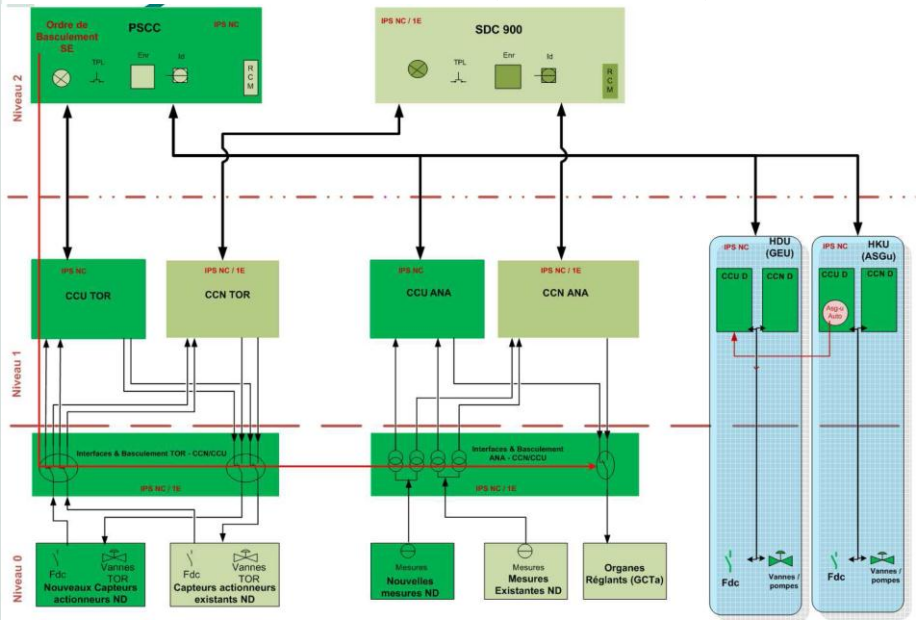
Ultimate water source and distribution



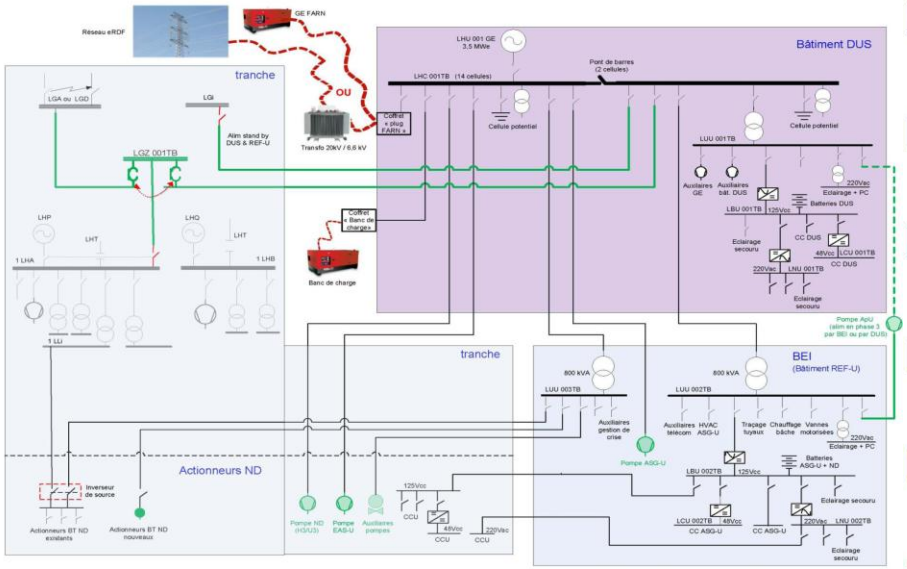
ultimate heat removal system



ultimate I&C (i.e. CPY serie)



Hardened safety core electrical systems

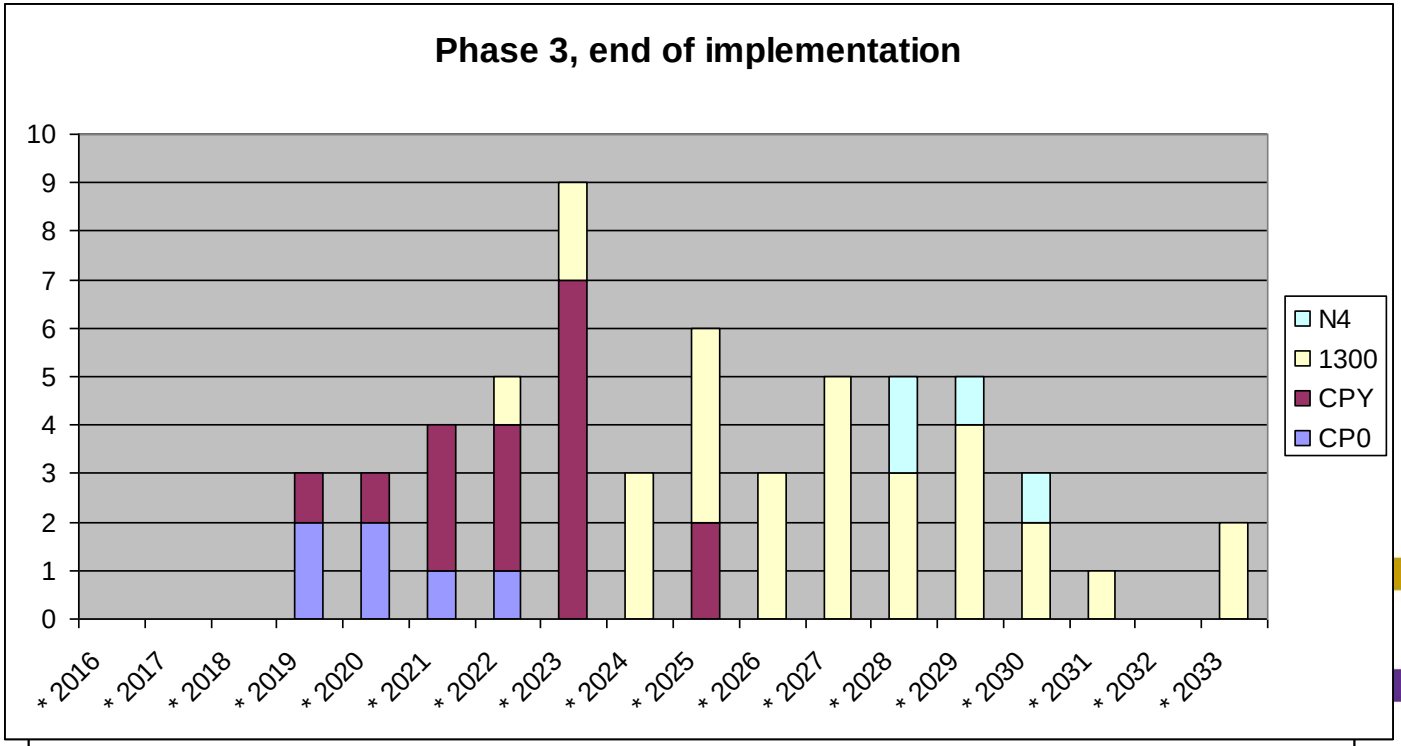


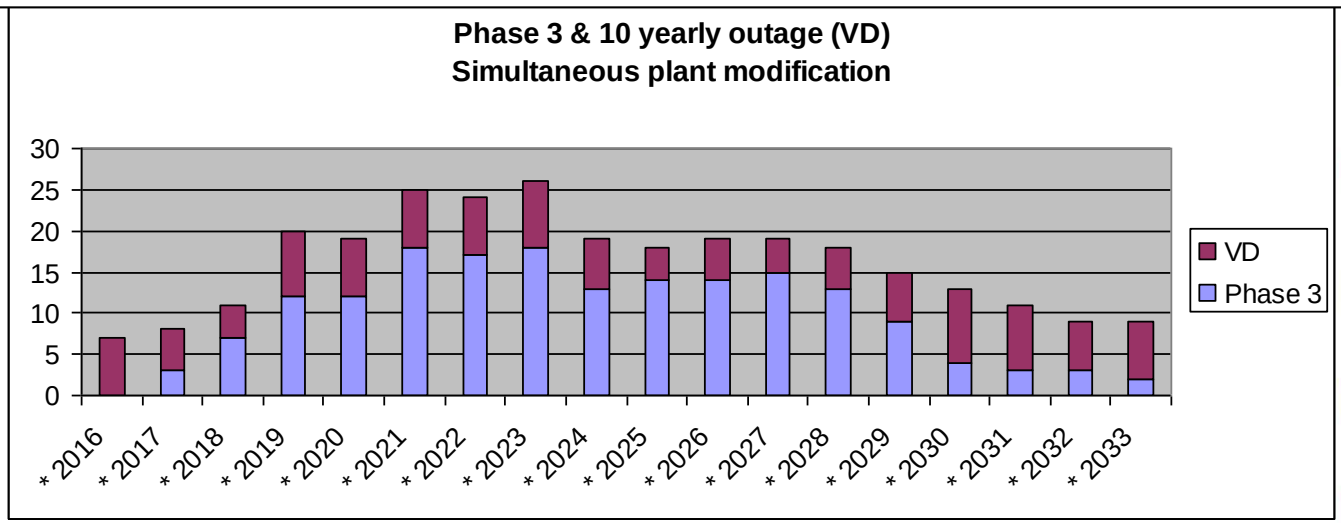
Phase 3

Status

ASN position on EDF timeschedule proposal :

2015





Validation of design hypothesis for the hardened safety core design

- Phase 2 and phase 3 hardened safety core design hypothesis will be examined by ASN,
- ASN will verify that solutions proposed by the licensee will meet safety objectives
- On the basis of the file submitted by EDF and the studies still to be carried out, ASN will ask the standing group of experts for its opinion on the most important issues
- **EDF started hardened safety core construction with design provisions to meet implementation deadlines (and will proceed to adjustments if required)**

Validation of design hypothesis for the hardened safety core

Extreme natural hazards (GP1)

- definition and justification of the levels of the natural hazards adopted by EDF for the hardened safety core of the PWRs. The natural hazards considered on the basis of the stress test specifications are earthquakes, flooding and "other natural hazards".

  Projected date of meeting: early 2016

Control of accidents (GP2)

- the examination will focus primarily on the strategies for operational management of accidents that can occur on the reactor, the pool and on the functional adequacy of the equipment (new or existing) for the accidents.

  Projected date of meeting: early 2016

Validation of design hypothesis for the hardened safety core

Control of severe accidents (GP3)

- new measures proposed by EDF to mitigate the consequences of a core meltdown accident in the short and long term.
- principles of the new measures
- measures adopted to remove the residual power from the reactor containment and the functional and design requirements of the systems used (containment venting-filtration system, containment ultimate spraying system, etc.),
- measures adopted by EDF to limit as far as reasonably possible the risk of basemat melt-through in the event of a core meltdown accident,
- accident situations covered by the measures (robustness against hazards, situations that might be excluded, etc.),
- optimisation of the measures adopted to limit as far as reasonably possible radioactive discharges into the environment and the possibilities of cliff-edge effects during the progression of an accident.
- *Projected date of meeting: early 2016*

Validation of design hypothesis for the hardened safety core

Ability to manage complex accident situations (GP4)

- effectiveness of the material and organisational measures implemented by EDF on each nuclear power plant site.
- the organisational and managerial measures planned by EDF to cope with a complex accident situation (in particular the prioritised management of the different types of action to be accomplished on the nuclear power plant site, the adequacy of the procedures and the operational control guides, the complementarity between the means of the site and those of the FARN),
- the sufficiency and robustness of the fixed and mobile equipment,
- human intervention under adverse conditions, the link between site own resources and FARN resources, and the management of contaminated waters.
- *Projected date of meeting: 2018*

Conclusion

- Post Fukushima measures implementation (phase 1 & Phase 2): on time
- Hardened safety core design hypothesis will be verified by ASN standing group of experts (2016 trough 2018)
- First implementation of phase 3 modifications: 2019

French periodic safety reviews comprise safety reassessment

Additional safety improvement may be required in the course of future PSR