Overview of AREVA's EPR™ Reactor

Andrew Teller
Senior Advisor, Technical Communication
Products & Technology, Cross-Cutting Activities

September 2010

EPR™ Development Goals

1. *“ **Evolutionary design** ” to fully capitalize on the design, construction and operating experience based on the 86 AREVA's PWR operating worldwide.*

2. ***Enhanced Safety** compared to operating PWRs **:***

   - *reduce core damage frequency (CDF),*
   - *accommodate severe accidents with no long-term population effect,*
   - *Withstand large airplane crash.*

3. ***High availability***

4. ***Simplified operation and maintenance.***

5. ***Generation cost at least 10 % lower than 1500 MWe series in operation.***

► ***Improved investors, operators and community confidence***

Joint Recommendations of French and German Safety Authorities (1993)

Three main objectives:

- **Evolutionary rather than revolutionary design;**
- **Significant reduction of core meltdown probability and improvement of the reactor containment capability (also for severe accidents);**
- **Improvement of operating conditions:**
  - **radiation protection,**
  - **waste management,**
  - **maintenance,**
  - **reduction of human error risk**

For the 1st time, 2 Safety Authorities combine their efforts to establish a common safety reference

Building on the Achievements of the N4 and Konvoi Reactors

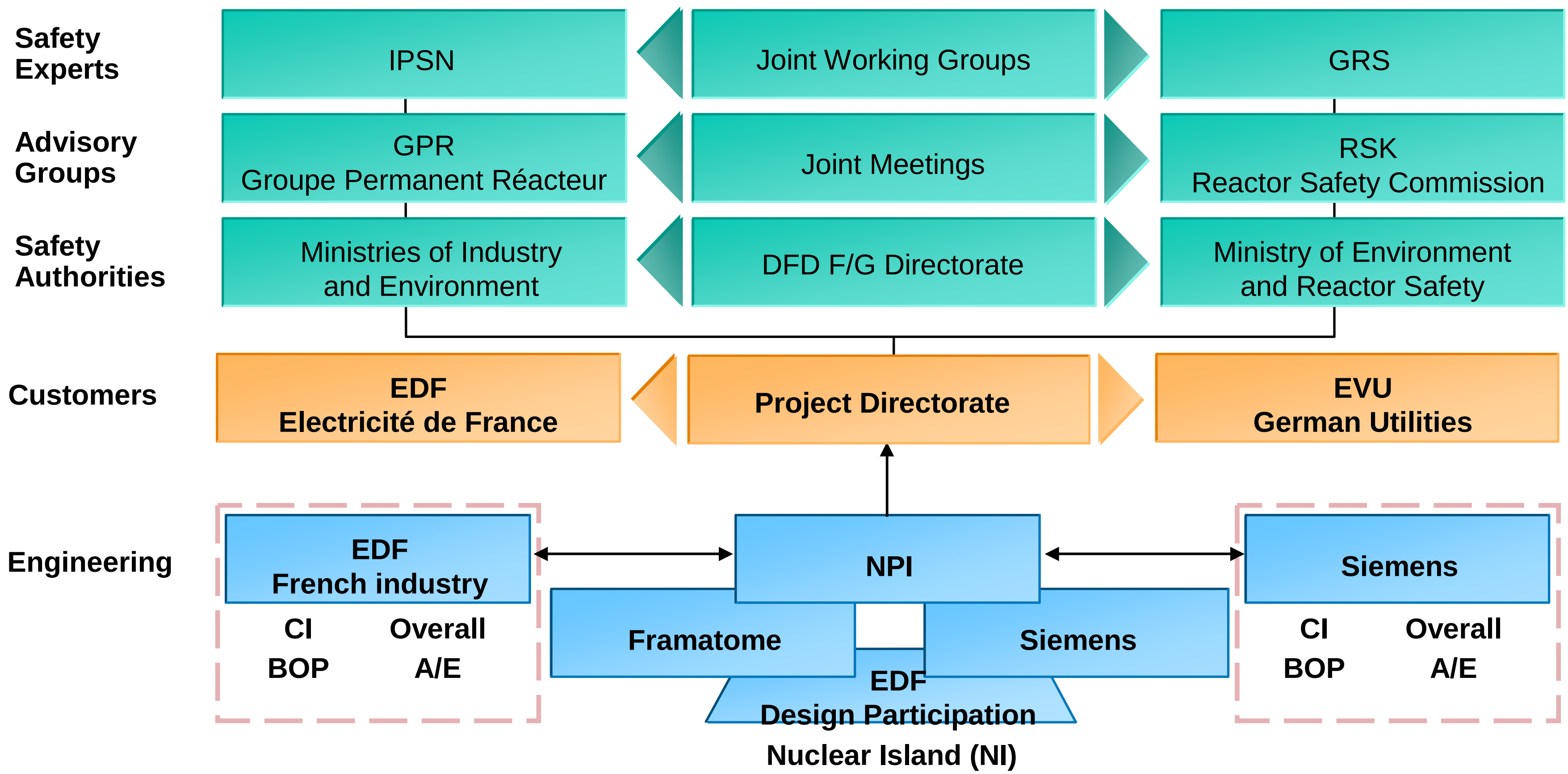
		EPR™ by AREVA
N4	High output (1475MWe)	Very High output: ~1600MWe
	Large core (205 FA)	Very large core: 241 FA
	High steam pressure (73,1 bar)	Very High steam pressure: 77,2 bar
	Fuel building	Fuel building
	Computerized MCR	Computerized MCR
	Concrete cylindrical containment	Best-in-class APC resistance
KONVOI	Military aircraft resistance	
	4 independent Safety trains	4x100% independent Safety trains
	No spray system	DBA: No spray system
	Top mounted instrumentation	Top mounted instrumentation

» **The EPR™ design combines, and improves on, the best features of the French and German technologies**

Main plant data

Type of plants	N4	EPR™	KONVOI
Core thermal power (MWth)	4250	4590	3850
Electrical output (MWe)	1475	1660	1365
Number of loops	4	4	4
N° of fuel assemblies	205	241	193
Type of fuel assemblies	17x17	17x17	18x18
Active length (cm)	427	420	390
Total F.A. length (cm)	480	480	483
Rod linear heat rate (W/cm)	179	166,7	167
N° of control rods	73	89	61
Total flowrate (kg/s)	19420	22220	18800
Vessel outlet temp. (℃)	330	330	326
Vessel inlet temp. (℃)	292	295.2	292
S.G.: heat exch. Surface (m^2)	7308	7960	5400
Steam Pressure (bar)	73	77	64.5

Basic Design Organization
(Up to early 2000 for the industrial organization - until end of 1998 for the involvement of the German Safety Authorities))

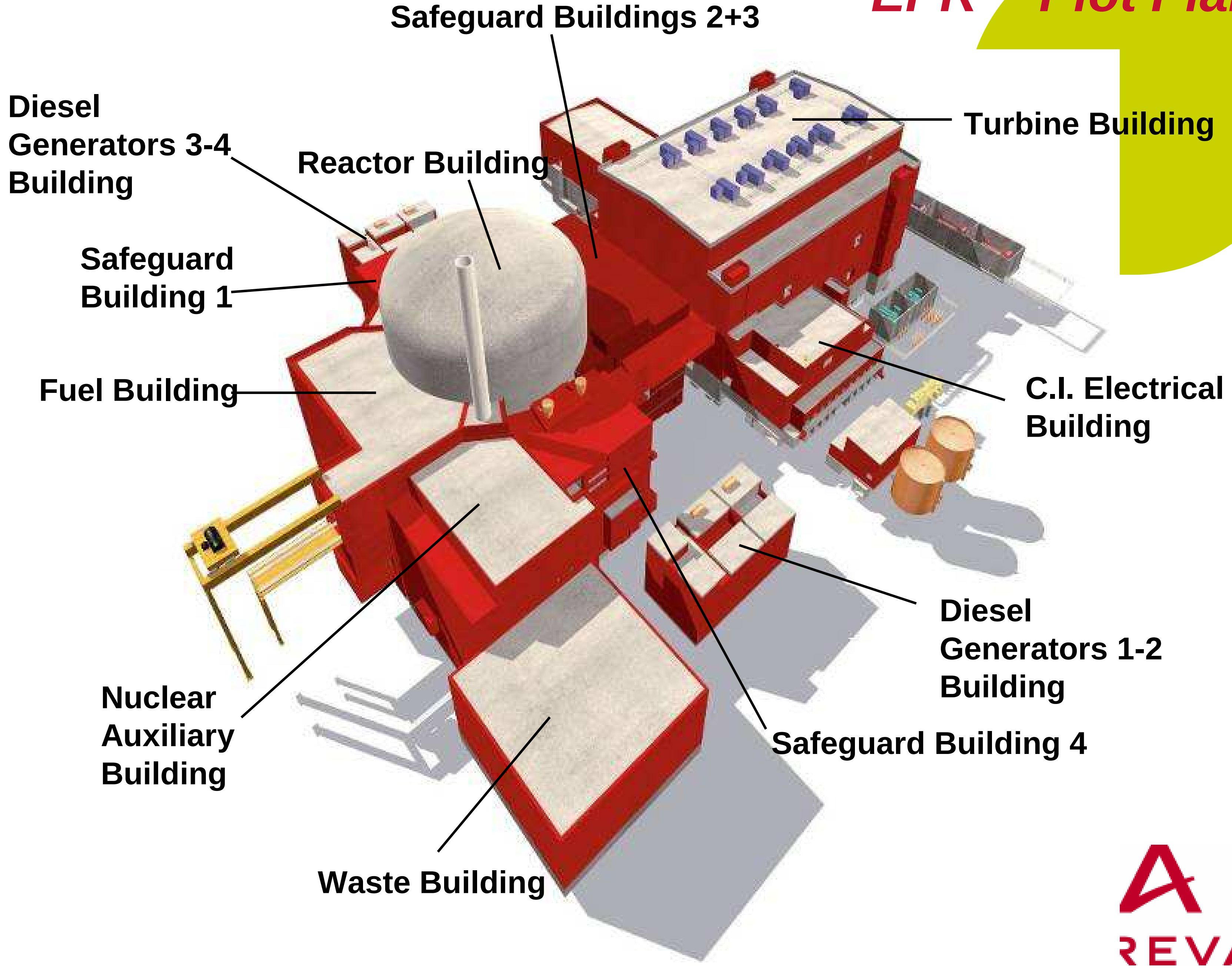


EPR™ Design Goals Meeting Utilities Needs

- **Decision of EDF and the German utilities in 1991 to join the EPR™ development**
  - **French and German utilities involved early in assessment of technical options**
- **EPR™ is designed to meet the European Utility Requirements (EUR)**
  - **Assessment first performed by utilities in 1999**
  - **Update of the assessment completed in 2009**

AREVA

EPR™ Plot Plan



EPR™ PLOT PLAN

1 Reactor Building

2 Fuel Building

3 The Safeguard Buildings

4 Diesel Buildings

5 Nuclear Auxiliary Building

6 Waste Building

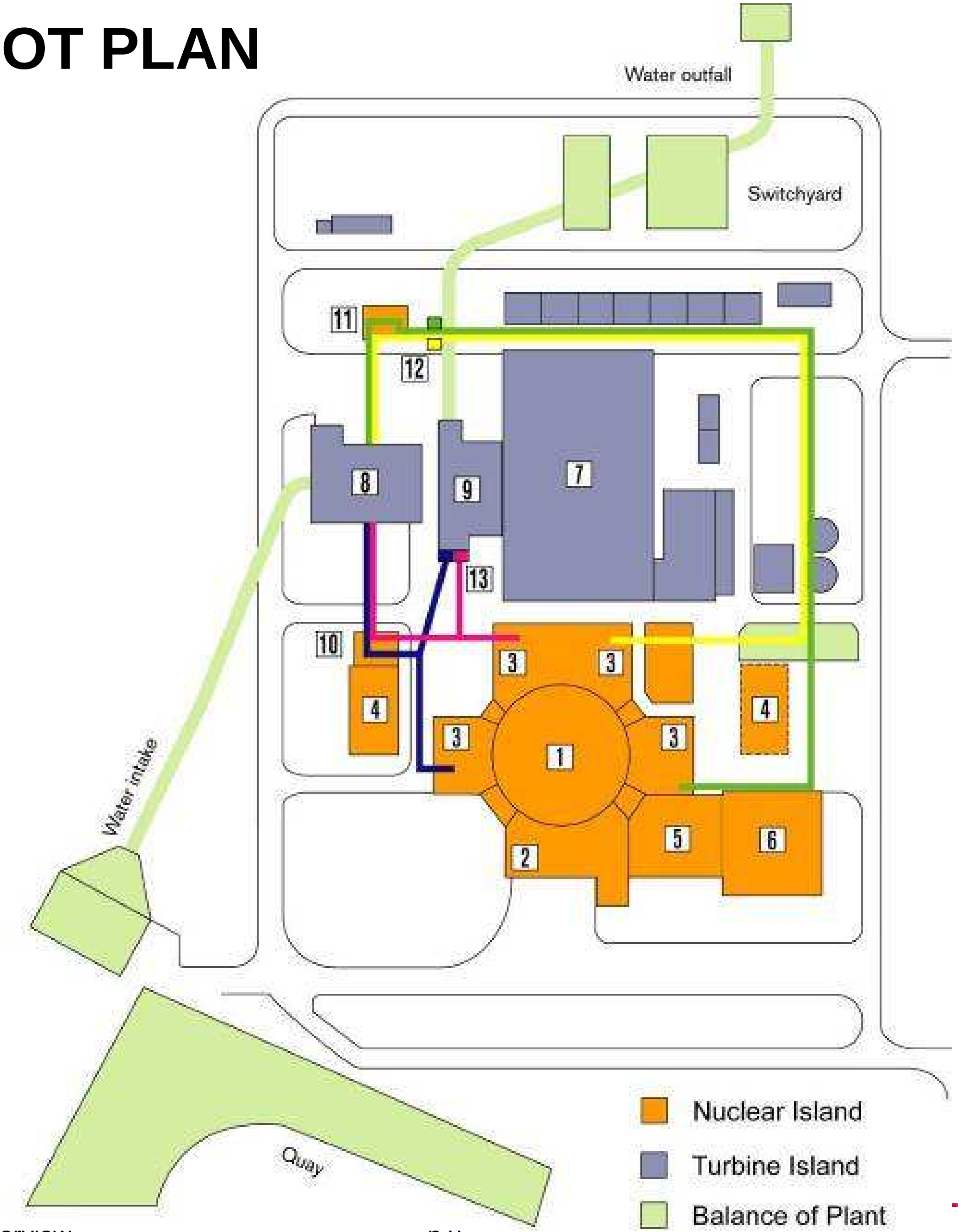
7 Turbine Building

8 Circulating Water Pumps Building

9 Circulating Water Seal Pit

10 11 Essential Water Pumps Building

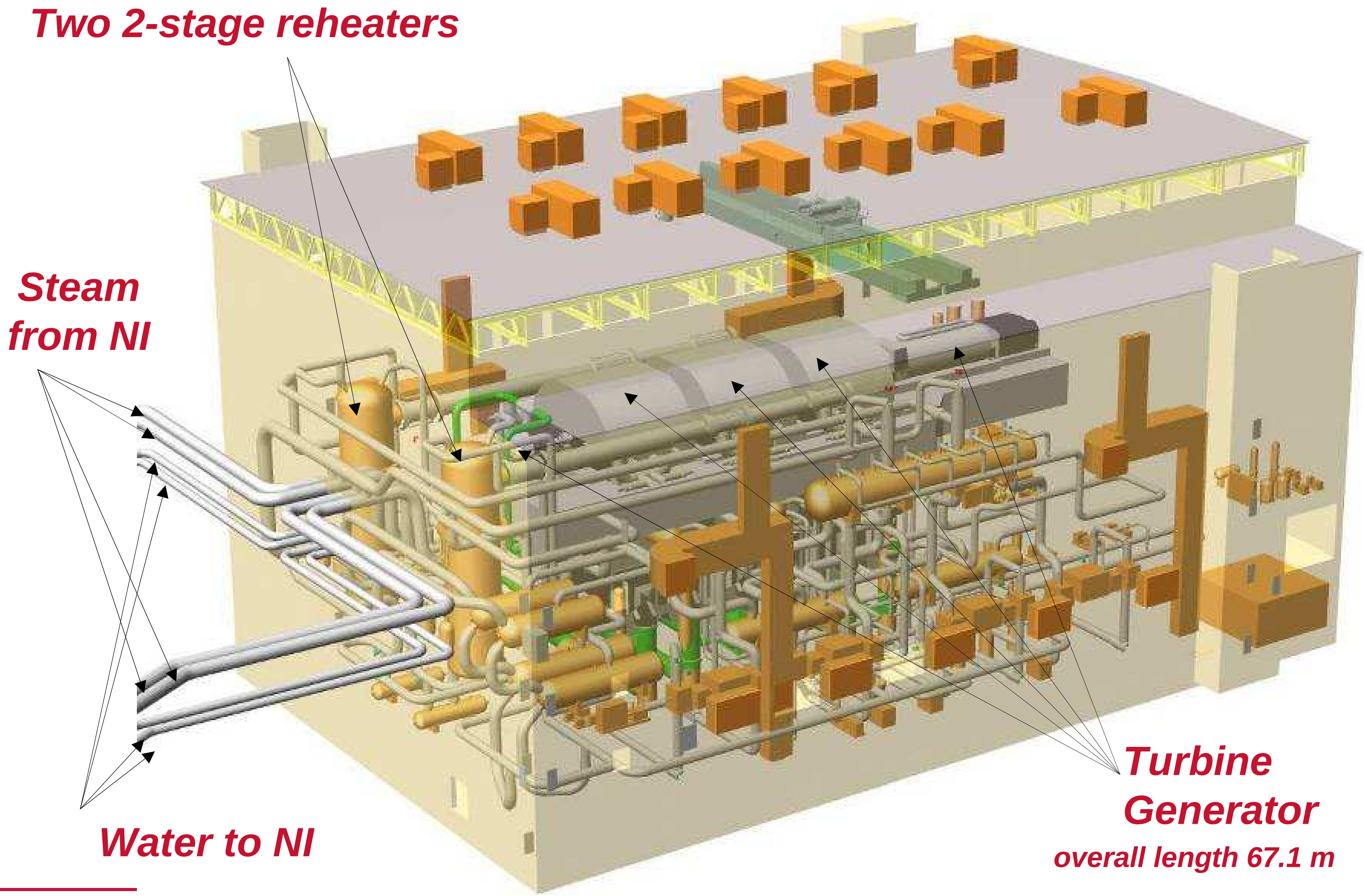
12 13 Service Water Collecting Pond



Train 10/50
Train 20
Train 30
Train 40/80

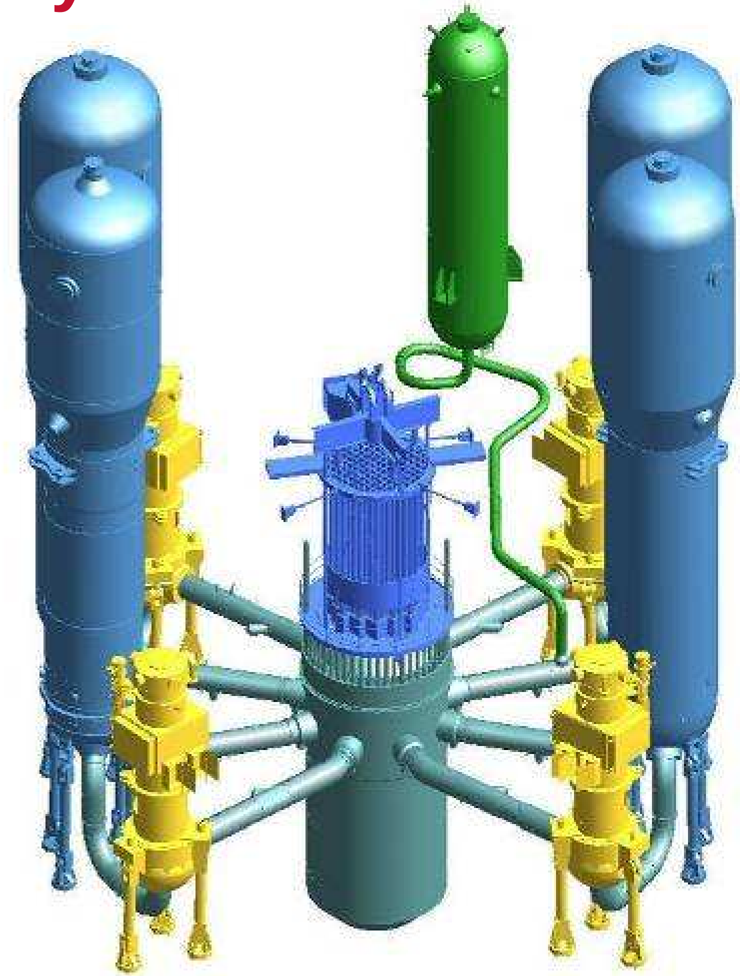
Concrete Channels for Essential Service Water System

Turbine Building OL3 Configuration



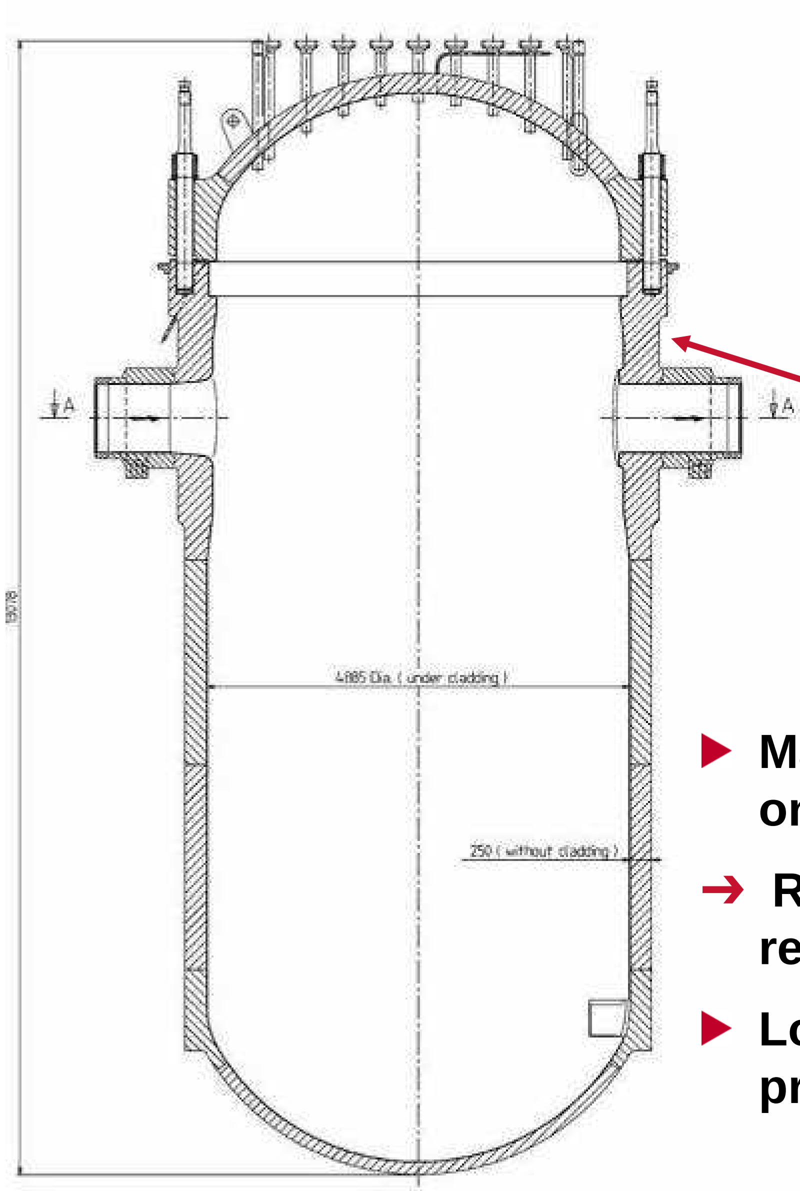
EPR™
Primary System Features

- Primary System with a 4-loop configuration is very close to existing designs
- Main components enlarged as compared to those in operation to increase grace period in many transients and accidents
- Extensive use of forgings with integral nozzles
- Materials resistant to corrosion and cracking



Proven design components

Reactor pressure vessel



- Main flange and nozzle shell in one piece: less welds

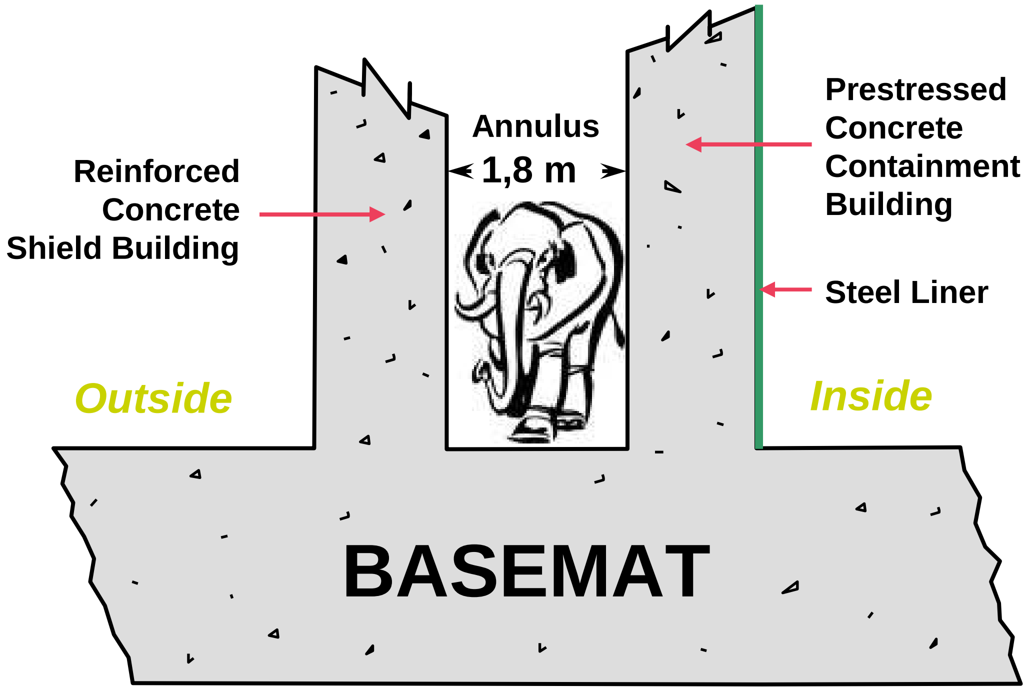
➔ Reduction of inspection time required for ISI

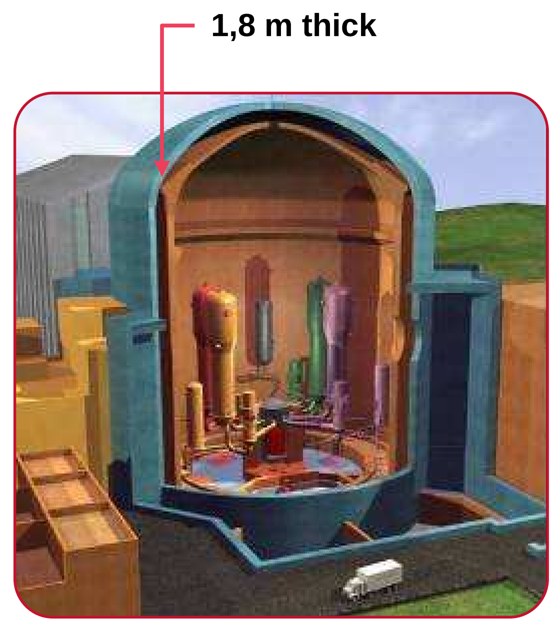
- Low level of neutron flux on pressure vessel

Containment and Confinement

- **Double wall containment :**
  - **Inner shell : pre-stressed concrete with a steel liner**
  - **Outer shell : reinforced concrete**
- **Annulus between double-shell is maintained at a sub-atmospheric pressure**
- **All leakages are collected in the annulus**
- **Filtration prior to stack release would further reduce radioactive aerosols**

EPR™ Reactor Safety Systems:
Best-in-class APC resistance





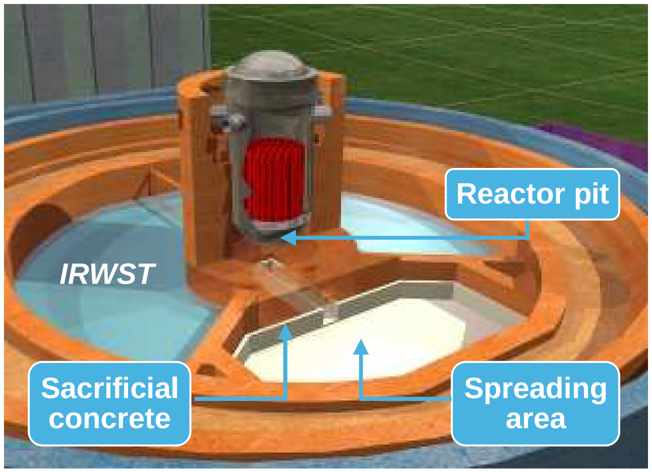
EPR™ Reactor, Fuel and two Safeguard Buildings are airplane crash resistant for both military and commercial aircraft:

- No licensing delay
- Bolstering public and political acceptance

AREVA

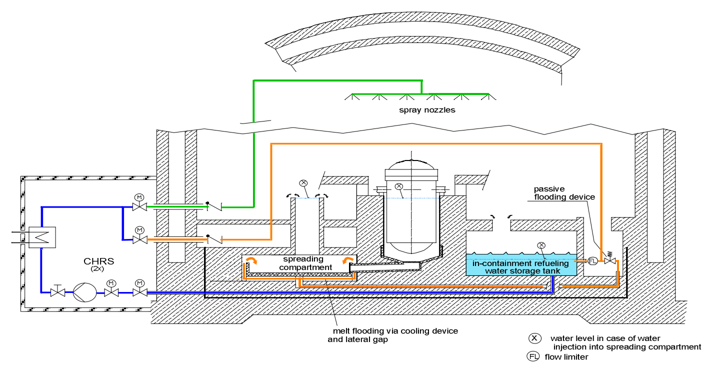
EPR™ Reactor Safety Systems:
Protection of the environment with Passive and Active Systems

Passive System (Short-term)



&

Active System (Long-term)



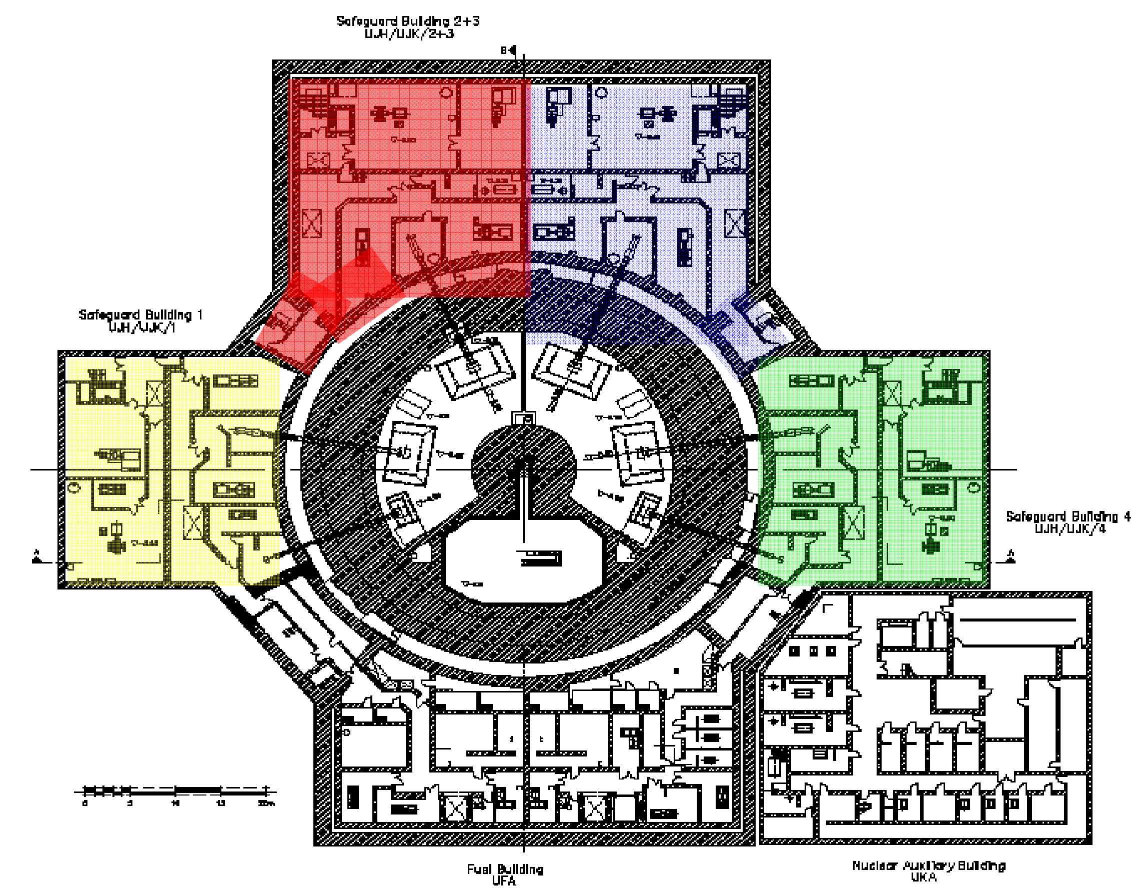
1. **Temporary retention in the reactor pit (gravity and metal gate)**
2. **Spreading in the large surface dedicated area (metal gate melting and gravity)**
3. **Flooding and cooling of the spreading area using IRWST (In-containment Refueling Water Storage Tank)**

1. **Removal of containment heat:**
   - **Recirculation and coolant heat exchange**
   - **Containment spray system**

Optimum severe accident mitigation prevent releases of hazardous material into the atmosphere and/or the soil

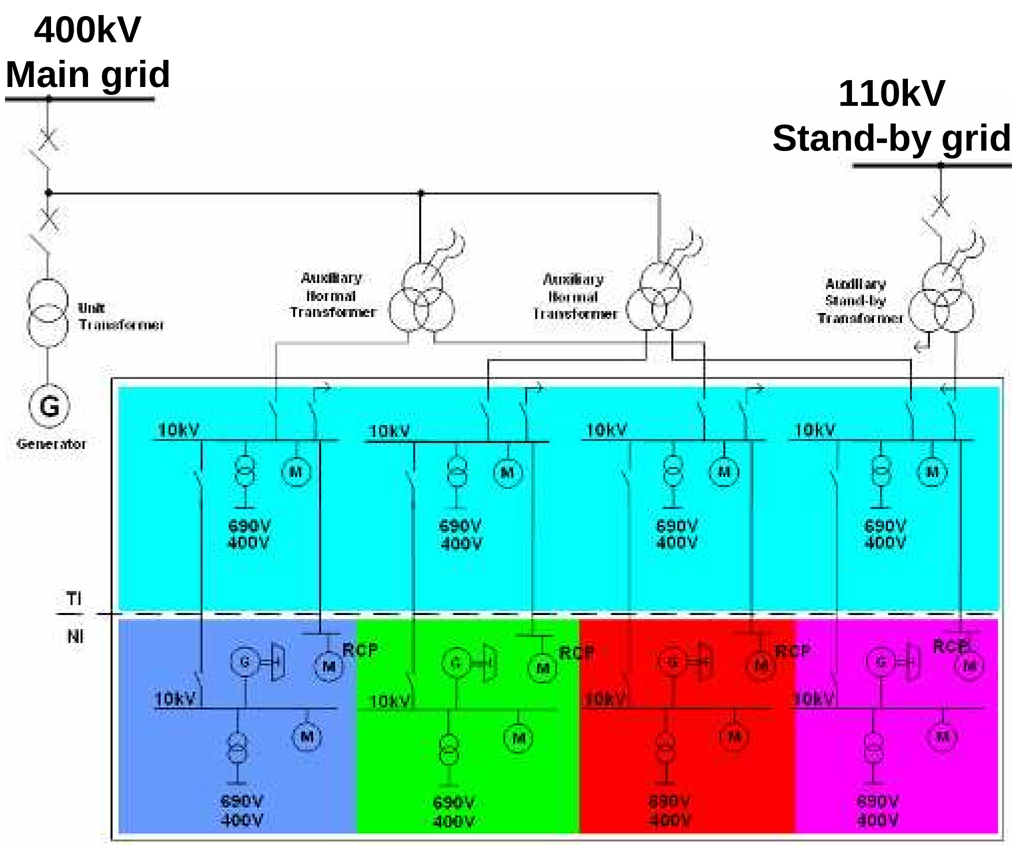
AREVA

Protection against internal hazards by divisional separation

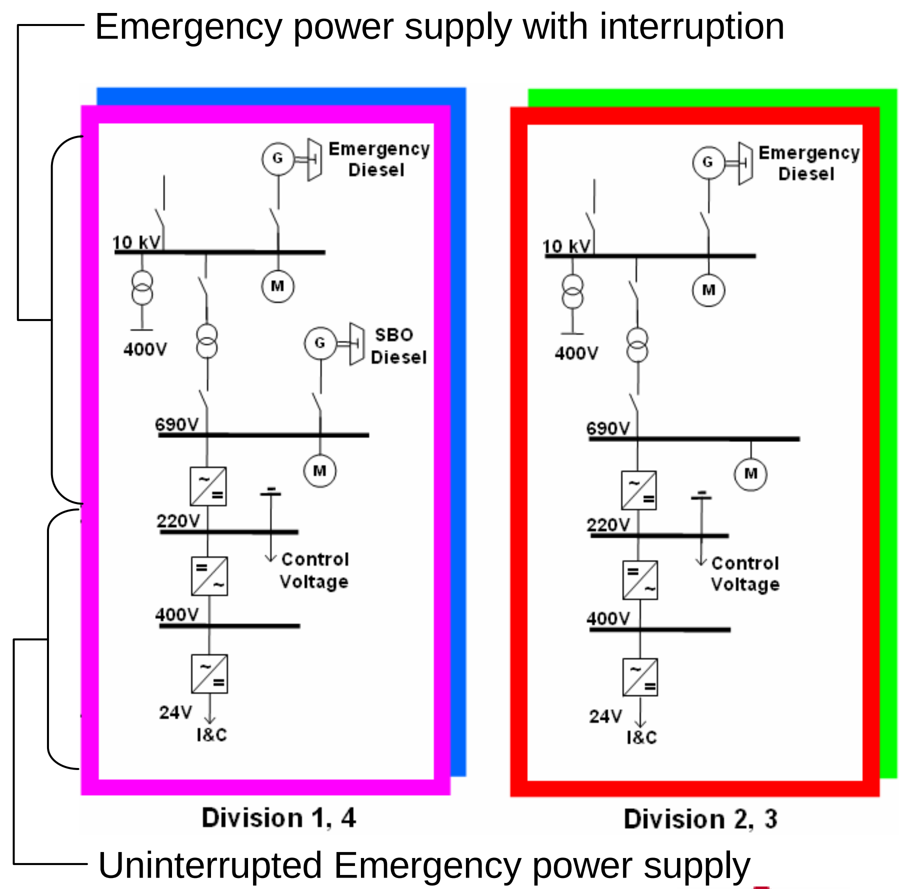


EPR™ Reactor Safety Systems:
Diversified power source with back-ups

Two independent grid connections to ensure power distribution diversity



4 independent safety divisions, 2 with additional SBO Diesel



AREVA

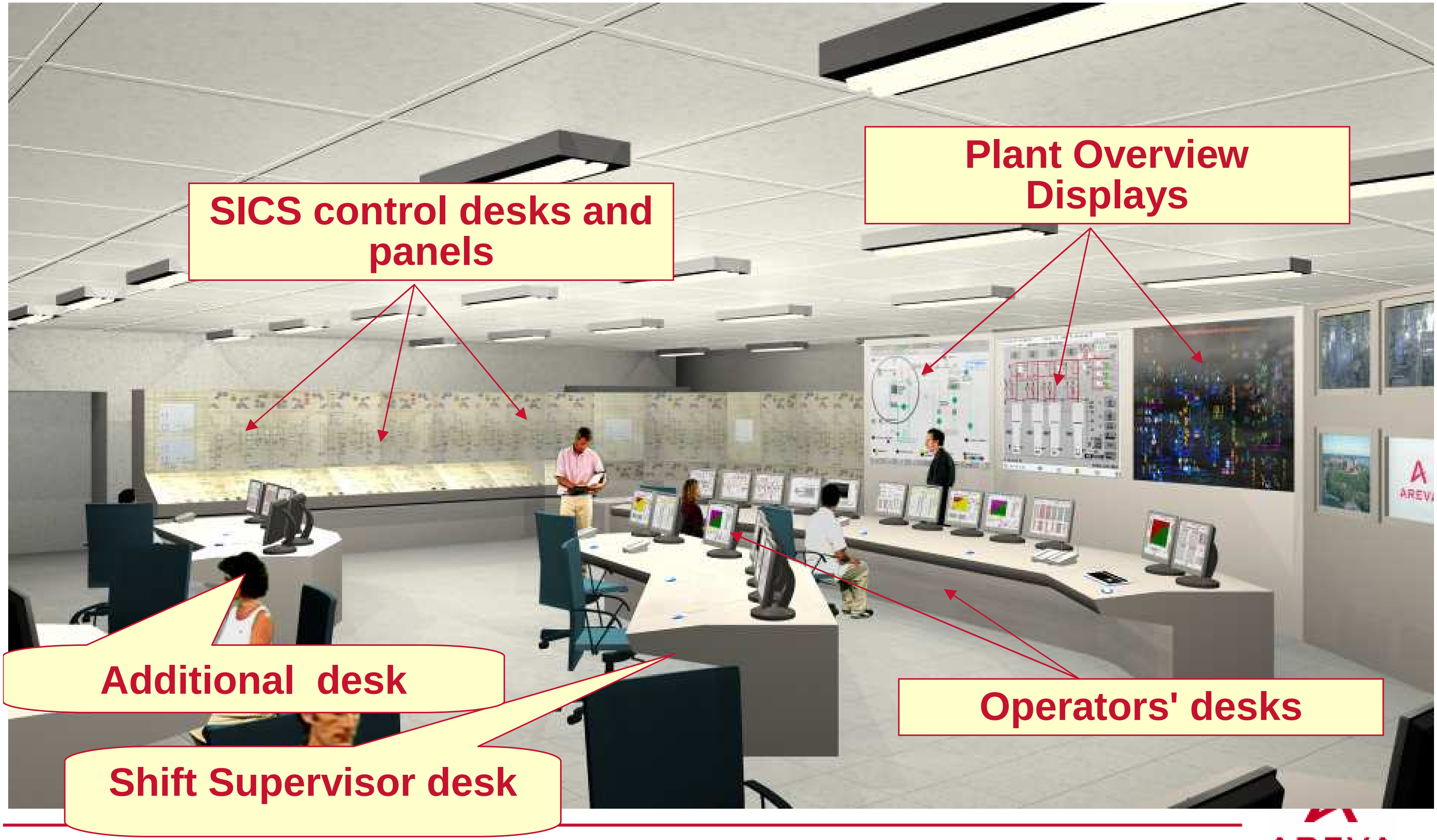
Instrumentation, Control and Man-Machine Interface Systems

Up-to-date technologies for digital I&C and computerized man-machine interface systems

Substantial experience feed-back to enhance :

- **Availability**
  - **Limitation functions decrease the unplanned reactor trips frequency**
  - **Design is fault-tolerant**
  - **Periodic tests are executed during plant operation**
  - **Detailed on-line diagnosis and modular structure allow corrective maintenance with minimum impact on plant operation**
- **Safety**
  - **Design is tolerant to common cause failures by hardware and software diversity**
  - **Optimized and simplified plant operation with guidance provided to operators**

EPR™ Main Control Room
General view



AREVA

EPR™ Optimized Generation Cost

1. Power level raised to 1600+ MWe
2. Steam cycle efficiency of 37 % (steam pressure of 7.7 MPa)
3. Better fuel utilization
4. Maintenance simplification
5. Short refueling outages
6. Reduction of personnel irradiation doses
7. Plant life time duration of 60 years

7 measures resulting in generation cost per MWh ~ 10% lower than for French 1500 MWe series

EPR™ load-follow capability

- **Usual load-follow : power level variation between 60% and 100% NP**
  - **Return to 100 % NP possible at 5%/min during 80 % of the fuel cycle**

- **Unusual load-follow : low power level between 25% and 60% NP**
  - **Return to 100 % NP possible at 2.5%/min during 80 % of the fuel cycle**

- **Extended operation at intermediate power level is possible without restriction neither on the duration nor on the power level**
  - **For less than 2 days of operation at intermediate power level, no additional restriction on load flexibility**
  - **For more than 2 days, additional constraints for returning to full power are accepted**

- **EPR™ reactor operating at intermediate power level must contribute to the spinning reserve by its capability of rapid return to full power**

AREVA

Licensing Achieved or under Way in 5 Countries

2005 STUK

2007 asn AUTORITÉ DE SÛRETÉ NUCLÉAIRE

2009 国家核安全局 NNSA

▶ EPR™ reactor

- In September 2004, the French Safety Authorities stated that the safety options of the EPR™ reactor met the safety enhancement objectives established for new reactors
- Construction license granted by Finnish and French Safety Authorities (Feb 2005 & Apr 2007 respectively), granted in China in Oct 2009
- US NRC design certification expected 3rd Q 2011, rulemaking in 2012; first COL (Calvert Cliffs) in 2012
- First reactor subjected to the Multinational Design Evaluation Program (MDEP) applied by US NRC, ASN (France), STUK (Finland) and NNSA (PRC). This sets favorable framework for EPR licensing in other countries

2011 U.S. Nuclear Regulatory Commission

HSE position in June 2011 HSE Health & Safety Executive

The AREVA Reactor Range

The AREVA Reactor range

GEN III+ KEY BENEFITS

BUSINESS PERFORMANCE

- Maximized availability: design target >92%
- Short outages
- High thermal efficiency
- Minimized global power generation costs
- Low O&M costs
- Fuel cycle flexibility
- MOX fuel

OUTSTANDING SAFETY

- Large commercial Airplane Crash resistance (APC)
- Advanced severe accident management
- Optimized level of redundancy, diversity of systems and incremental mitigation of abnormal events

ENVIRONMENTAL PROTECTION

- Minimal environmental impact
- Reduced collective dose

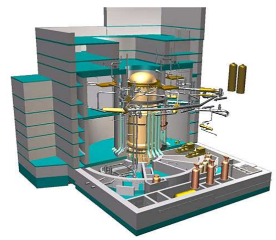
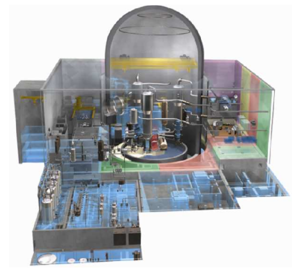
ENERGY SUPPLY CERTAINTY

- GenIII+ evolutionary designs
- AREVA integrated supply chain strategy for critical components
- Proven Digital Safety I&C technology
- Maximized standardization for simplified licensing

AREVA is the only player with a Gen III+ reactor range

- ▶The reference in Safety
- ▶Answer the varied customer needs with an adapted product portfolio

AREVA's reactor range


BWR 1250 MWe	PWR 1100 MWe	PWR 1650 MWe
KERENA™ by AREVA	ATMEA Developed in partnership with MHI	EPR by AREVA
Medium Power Output		High Power Output
Boiling Water Reactor	Pressurized Water Reactors	
Market launch: 2010		Deployed

AREVA

The ATMEA1™ Reactor

1 100 MWe PWR

ATMEA1™

The mid-sized GenIII+ PWR

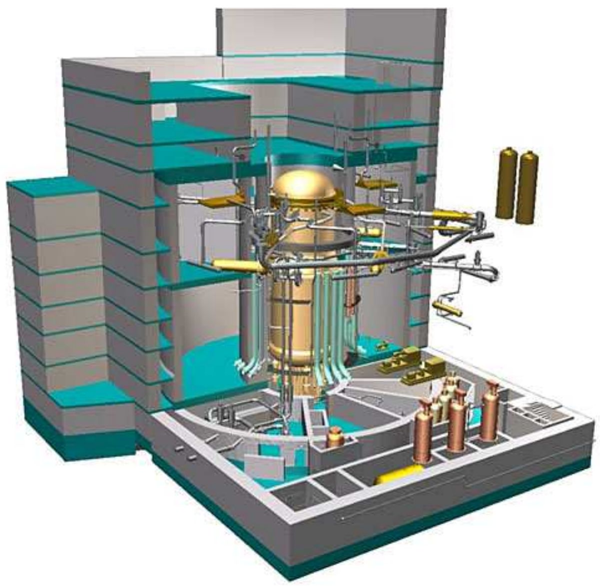
- **Generation III+ PWR**
  - **3-Loop**
  - **2 860 - 3 150 MWth**
  - **SG pressure 71b at 100% power**
  - **3x100% redundancy of active systems, passive safety systems and an additional backup cooling chain**
  - **Backup in case of total loss of safety function**
- **Medium power output (1 100 MWe)**
- **Evolutionary design based on the EPR™ and MHI's APWR**
- **Outstanding safety level**
- **Minimal environmental impact**

Strong customer interest from GDF Suez

AREVA

The KERENA™ Reactor

1 250 MWe BWR



KERENA™ by AREVA

The mid-sized GenIII+ BWR

- **Generation III+ BWR**
  - **3 370MWth**
  - **Steam pressure 75b at 100% power**
  - **Diversity and redundancy of safety systems:**
    - 2 active safety systems
    - 4 passive safety systems
- **Medium power output (1 250 MWe)**
- **Design based on successful operation experience in the latest German BWRs**
- **Outstanding safety level**
- **Minimal environmental impact**

Strong customer interest from E.ON

Any reproduction, alteration or transmission of this document or its content to any third party or its publication, in whole or in part, are specifically prohibited, unless AREVA NP has provided its prior written consent.

This document and any information it contains shall not be used for any other purpose than the one for which they were provided.

Legal action may be taken against any infringer and/or any person breaching the aforementioned obligations.