Advanced Power Reactors in Korea

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Yong Soo Kim

KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

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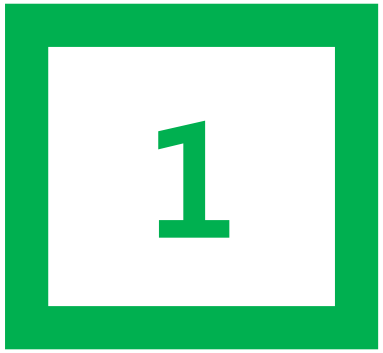
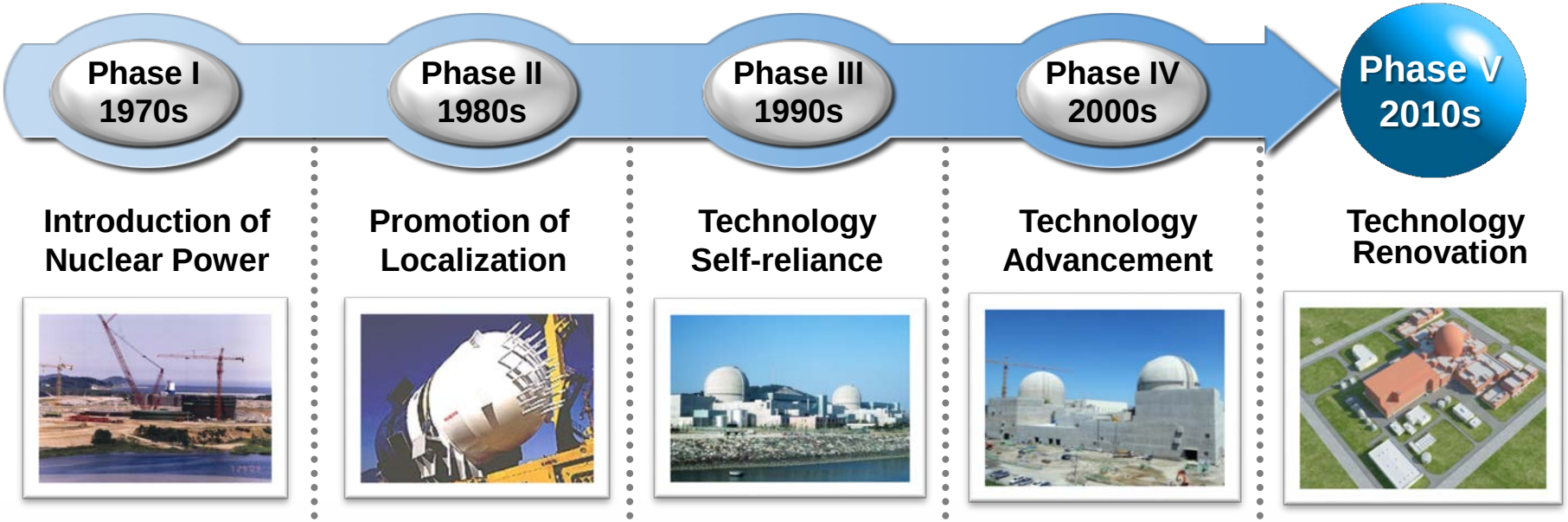


Introduction

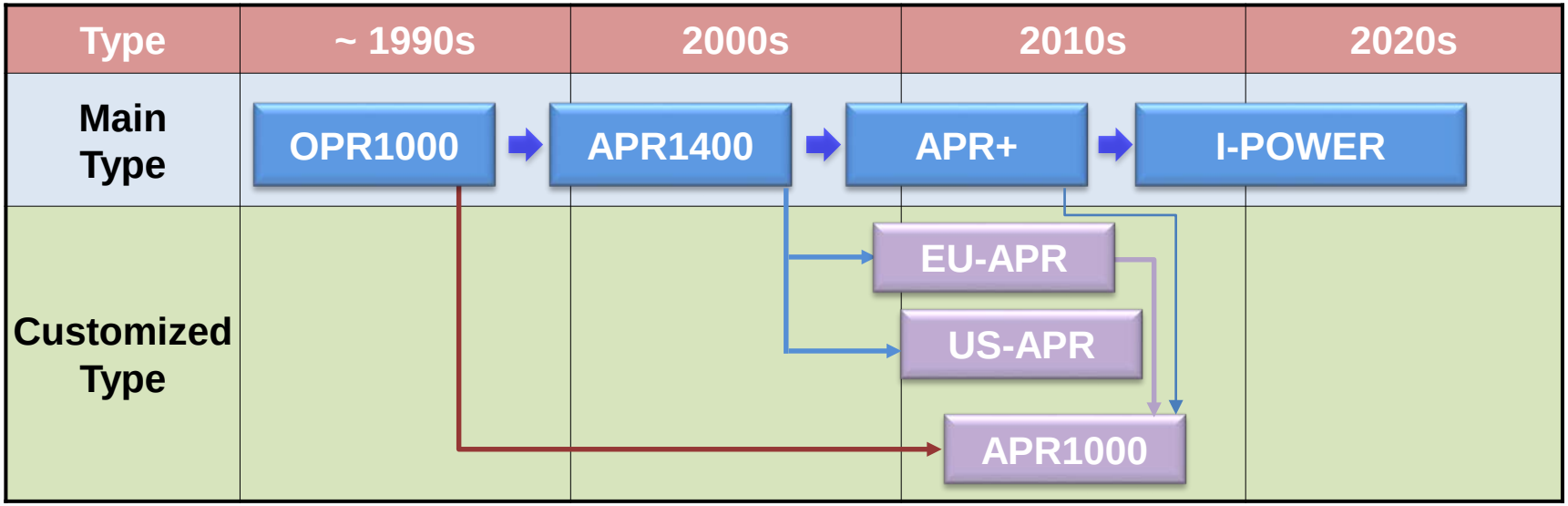
History of Nuclear Rector Development in Korea

- Continual construction of NPPs after introducing the first unit in 1971
  - 25 operating units, 7 units in Korea & 4 units in UAE under construction
- In addition, advanced reactors has been developed and the APR1400 customized designs assessed for Design Certification in USA & Europe



Strategy for Advanced Reactor Development

- **Short-term strategy**
  - Evolutionary development of advanced reactors and demonstrating their performance through domestic construction & operation : **APR1400**, APR+
  - Performing customized engineering for advanced reactors to comply with market demands in capacity & regulation : **EU-APR**, **APR1000**, US-APR1400
- **Long-term strategy**
  - Revolutionary development to improve NPP safety innovatively : I-POWER
- **Roadmap of Advanced Reactor Development**



2 European Advanced Power Reactor (EU-APR)

Technical Background of EU-APR

- **APR1400 developed to fully comply with US regulations for ALWR and EPRI utility requirements**
  - 1 operating unit, 7 units in Korea & 4 units in UAE under construction
- **EU-APR customized for Europe based on the reference plant (SKN 3&4) design**
  - Incorporating EUR Rev. D, IAEA SSR-2/1, WENRA requirements, and recommendations of EU Stress Tests

Comparison of APR1400 Series Designs

Parameters		SKN 3&4	UAE	NRC-DC	EU-APR
Design Criteria Base		10CFR, NRC RG	10CFR, NRC RG	10CFR, NRC RG	IAEA, WENRA, EUR
Metrication		British	British	British	SI
Frequency		60 Hz	50 Hz	60 Hz	50 Hz
Codes & Stds	Mech.	ASME	ASME	ASME	ASME, EN
	Elec./I&C	IEEE	IEEE	IEEE	IEC
	QA	ASME NQA-1	ASME NQA-1	ASME NQA-1	IAEA GS-R-3, ISO
Acceptance Criteria for limiting DBC(LBLOCA)		250 mSv/2hr (TID-14844)	250 mSv/2hr (TID-14844)	250 mSv/2hr (TID-14844)	5 mSv (RST)
Redundancy of Safety Systems		Mech. 4-train Elec. 2-train	Mech. 4-train Elec. 2-train	Mech. 4-train Elec. 4-train	Mech. 4-train Elec. 4-train
Aircraft Crash Protection Design		Exclusion due to low APC Probability	Reinforced Primary Containment & Aux. Bldg	Reinforced Primary Containment & Aux. Bldg	Double Containment, Reinforced Aux. Bldg
Severe Accident Mitigation Systems		SAs Dedicated Sys. + DBC Mitigation Sys.	SAs Dedicated Sys. + DBC Mitigation Sys.	SAs Dedicated Sys. + DBC Mitigation Sys.	Dedicated Systems for SAs
I&C Architecture		2-platform	2-platform	2-platform	3-platform

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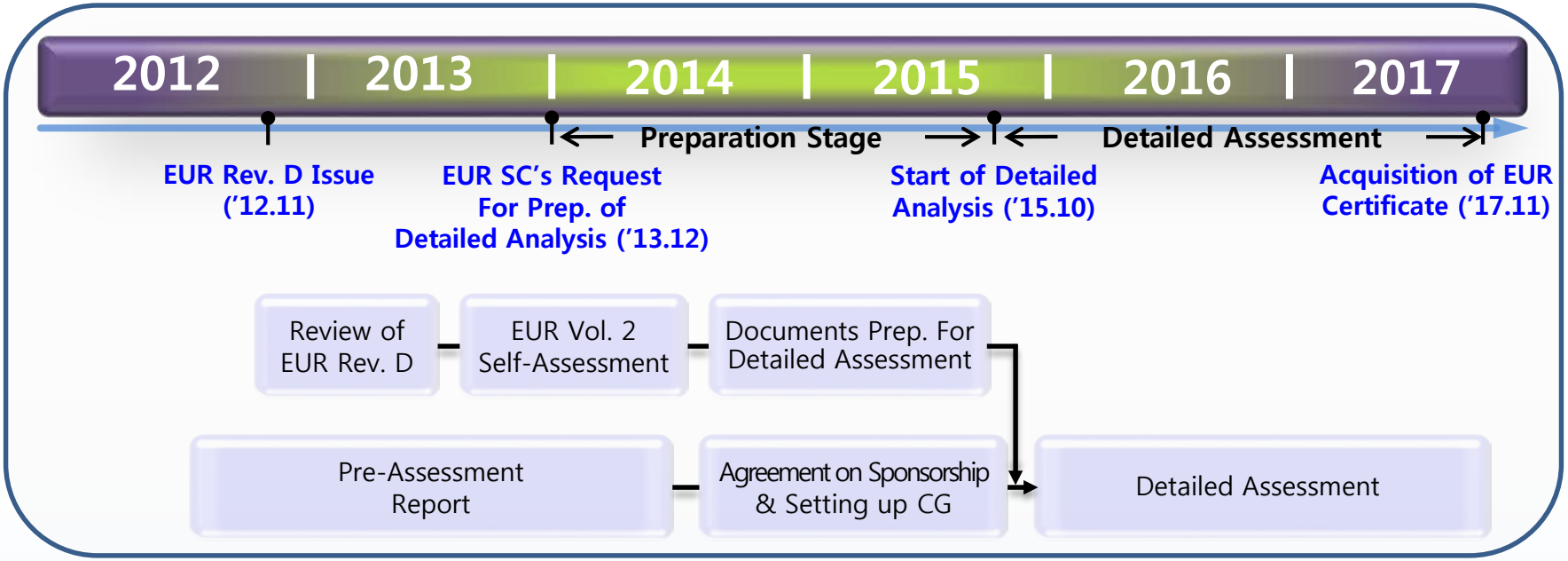
EUR Certification Project of EU-APR

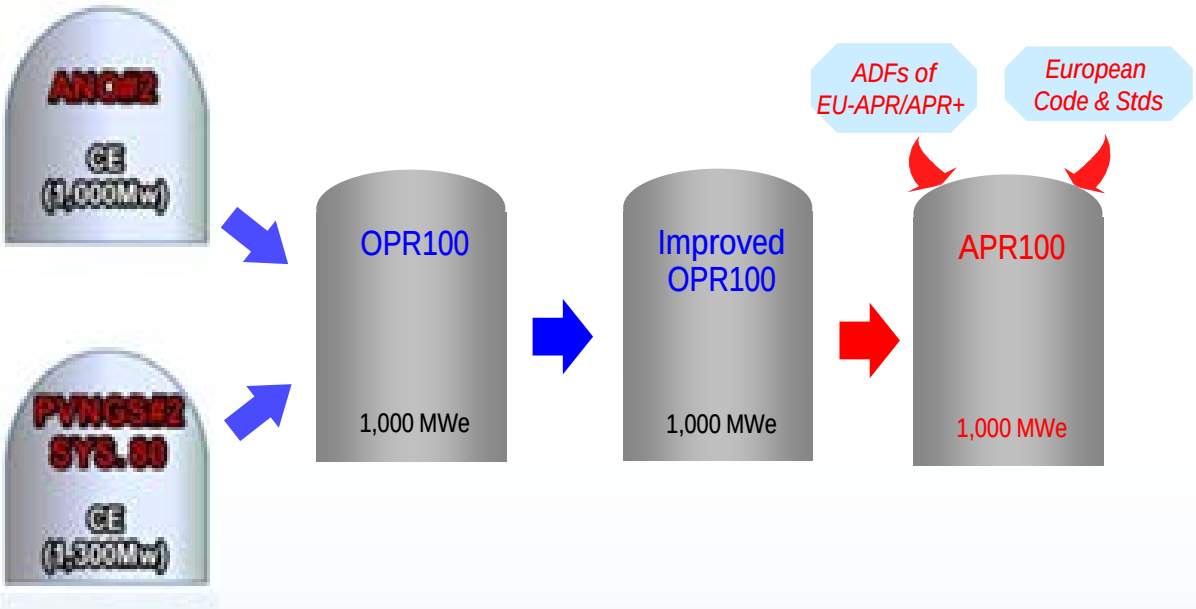
- **To establish the cornerstone for EU-APR to enter into the European market through obtaining EUR Certificate in 2017**
  - Applied to the EUR assessment on December 2011 and passed the preliminary assessment stage on December 2013
  - Detailed assessment was successfully finished this May and Certification to be issued on November 2017



3 Advanced Power Reactor 1000 (APR1000)

Technical Background of APR1000

- **OPR1000 developed by combining CE designs of ANO and PVNGS**
  - 12 units are operating in Korea from 1995
- **APR1000 is the customized design of OPR1000 for Europe by adopting Advanced Design Features of EU-APR and APR+**
  - Sep. 2014 ~ Sep. 2015 : Completion of concept design development
  - Aug. 2016 ~ Aug. 2018 : Developing the basic design of APR1000 NI



Comparison of OPR1000 & APR1000

Parameters		OPR1000(SWN 1&2)	APR1000
Design Criteria Base		10CFR, NRC RG	IAEA, WENRA, EUR
Metrication		British	SI
T/G		1,800 rpm, 60 Hz (GE)	3,600 rpm, 50 Hz (Doosan-Skoda)
Codes & Stds	Mech.	ASME	ASME, EN
	Elec./I&C	IEEE	IEC
	QA	ASME NQA-1	IAEA GS-R-3, ISO
Acceptance Criteria for limiting DBC(LBLOCA)		250 mSv/2hr (TID-14844)	5 mSv (RST)
Redundancy of Safety Systems		Mech. 2-train Elec. 2-train	Mech. 4-train Elec. 4-train
Aircraft Crash Protection Design		Exclusion due to low APC Probability	Double Containment, Reinforced Aux. Bldg
Severe Accident Mitigation Systems		SAs Dedicated Sys. + DBC Mitigation Sys.	Dedicated Systems for SAs
I&C Design		Analog	Fully Digital, 3-platform

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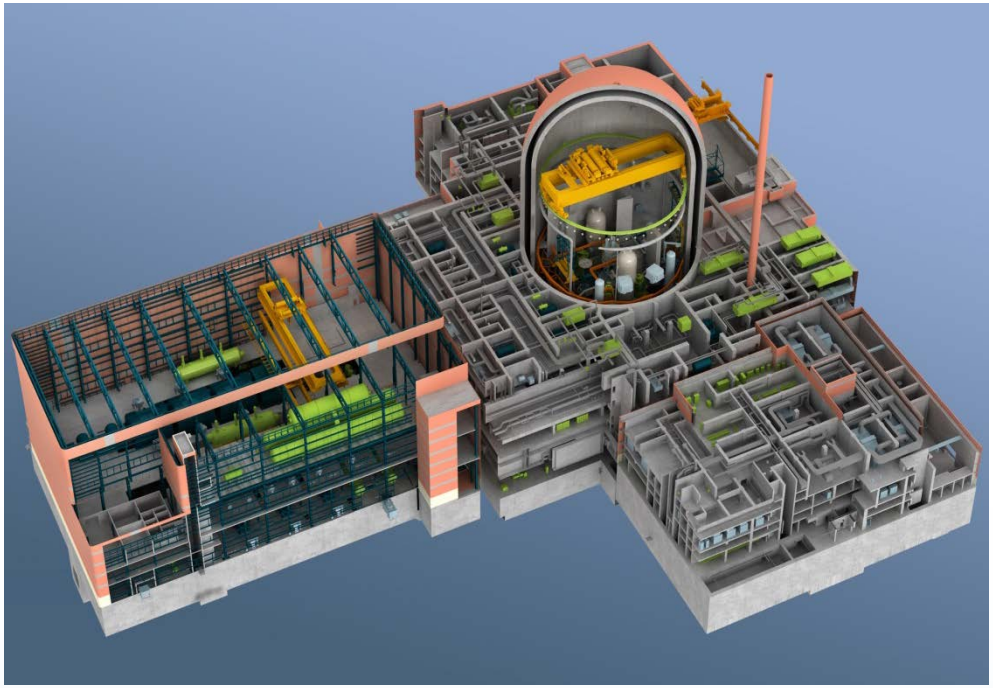
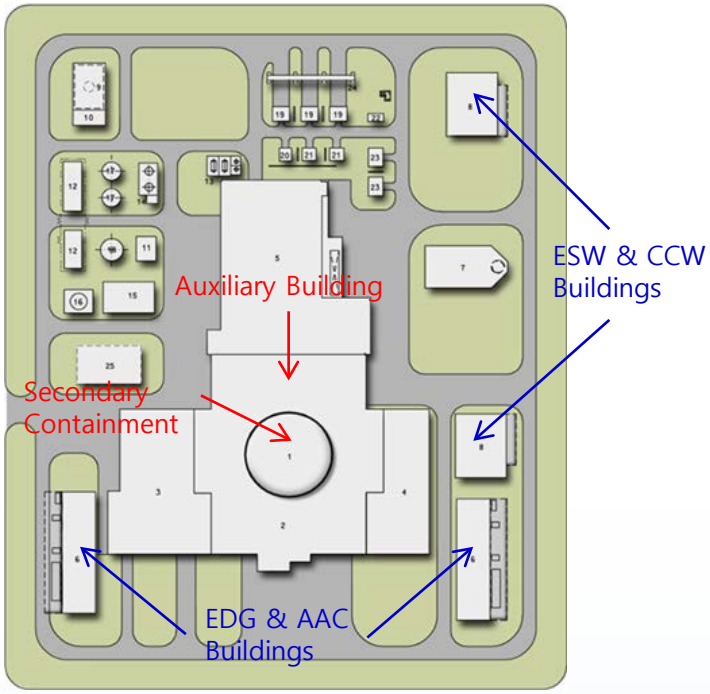
4 Major Advanced Design Features for EU-APR & APR1000

Building and Structure Design

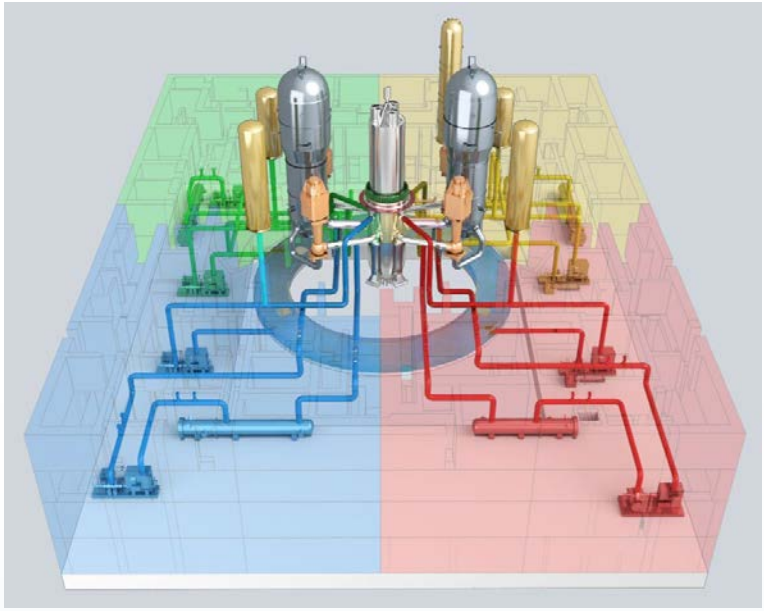
- Secondary containment and reinforced or physically separated arrangement of safety buildings against intentional airplane crash
- Stack to monitor discharged gas in the integrated manner and to enhance dispersion of discharged gas

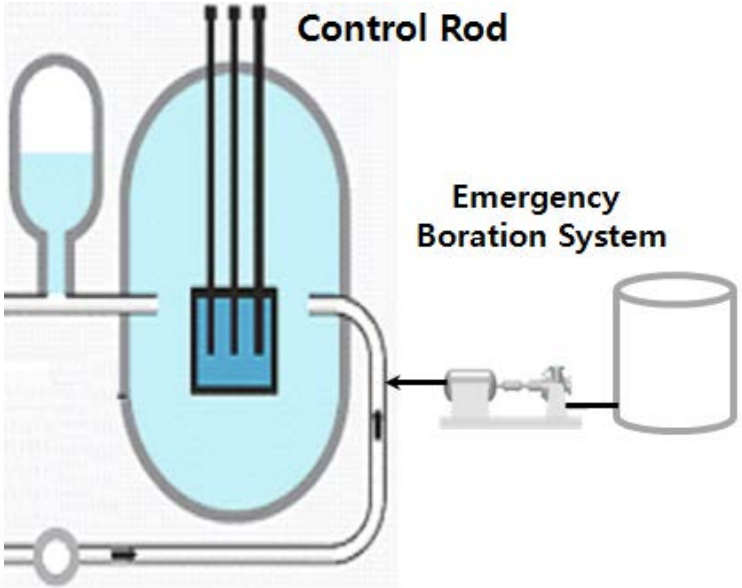




Safety System Design

- **Redundancy**
  - N+2 Design : SC-2 systems to mitigate DBC 3 & 4 accidents
  - N+1 Design : SC-3 systems to mitigate DBC 2, DEC and Severe Accidents
- **Diversity**
  - Equipping with system or component level alternative measures against CCFs of systems performing safety functions in the event of DBC 2 & 3

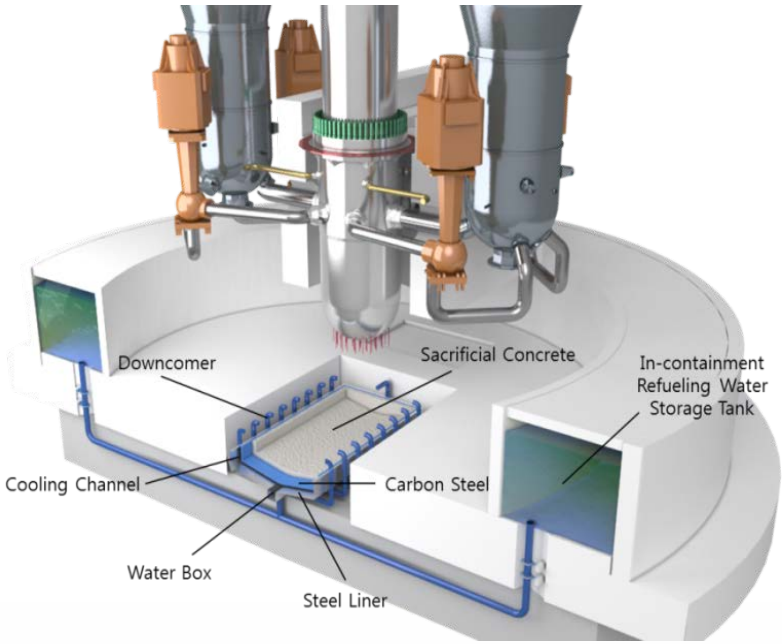




Dedicated Severe Accident Mitigation System

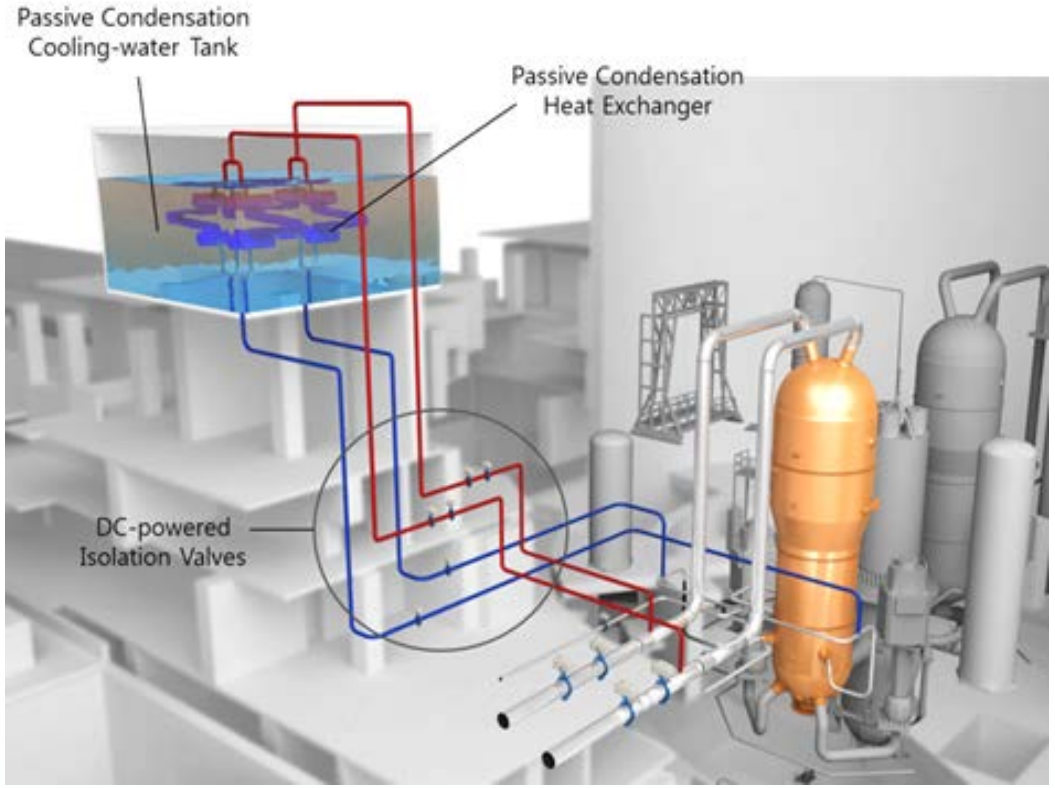
- **SAs dedicated mitigation systems to preserve the containment integrity independent of systems for Design Basis Conditions**

System	Function
Passive Corium Cooling System	Preventing interaction between molten core and pressure-bearing materials of the containment
Emergency Reactor Depressurization System	Preventing high pressure molten ejection
Containment Spray System	Preventing containment over-pressurization
Passive Hydrogen Control System	Maintaining hydrogen concentration in containment below 10 v/o
Instrument System	Monitoring status of plant condition
Electrical System	Supplying power to SAs dedicated systems by using battery and AACs



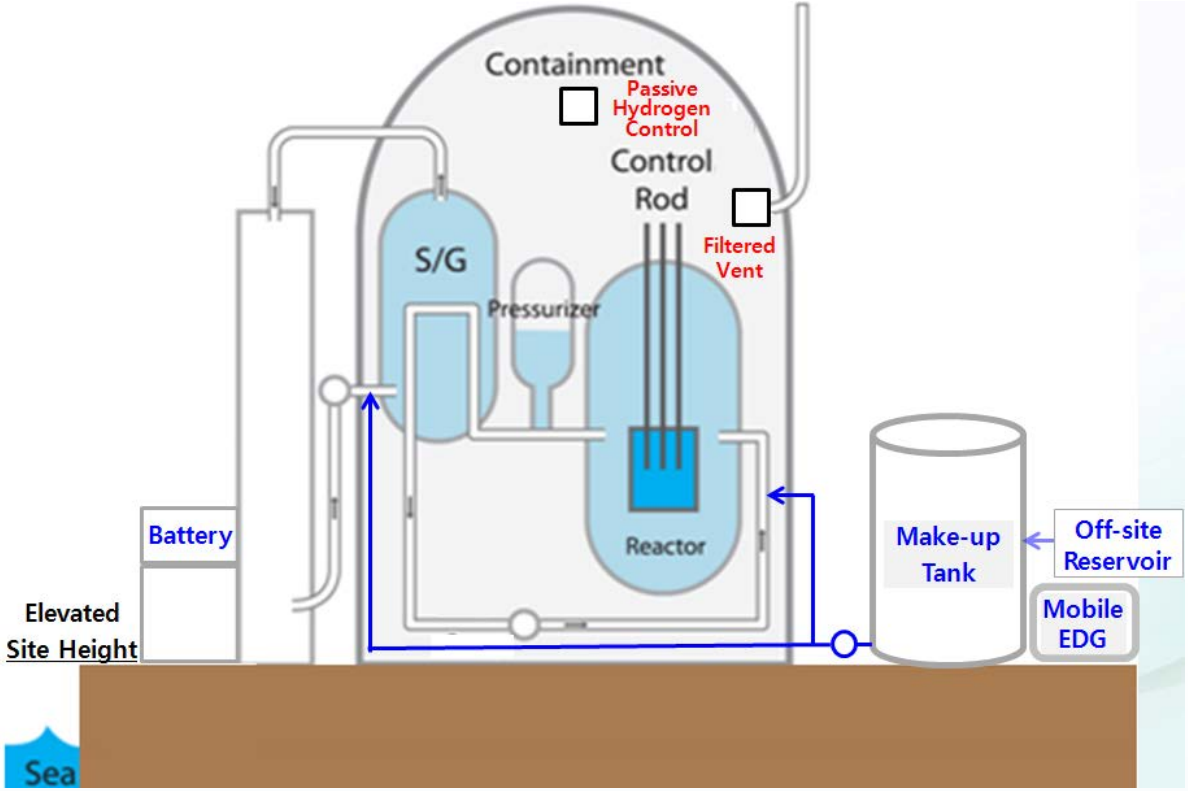
Passive Aux Feedwater System(PAFS)

- **Passive safety feature applied to APR1000, completely substituting conventional active Aux-Feedwater System(AFWS)**
  - Improving plant safety through core residual heat removal using natural force
  - Two independent trains, each train can remove 100% core residual heat
  - System initiation valve supplied from battery for at least 72 hours in the extremely rare event such as Fukushima Accident



Counter-Measures for Extremely Rare Events

- **Reinforced waterproof function against external flooding**
- **Protection designs against loss of electrical power & ultimate heat sink**
  - External injection path for emergency cooling of RCS, SG and SFP
  - Mobile generator, capacity-reinforced and flood-protected batteries



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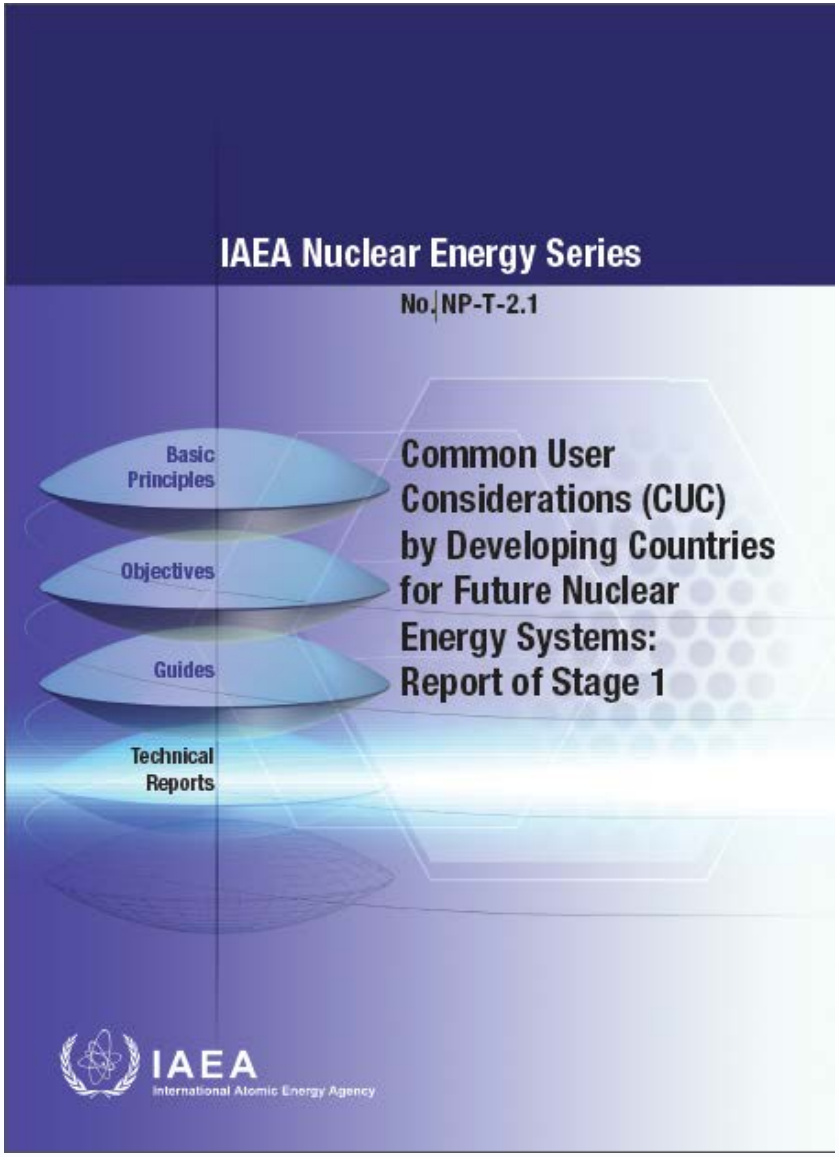
Why EU-APR & APR1000 are Proven Designs

Definition of Proven Design in IAEA



7.1 *Proven technology*

7.1.1 Proven technology should include overall nuclear power plant systems and elements. The elements should include components, plant structures, design and analysis techniques, maintainability and operability features and construction techniques.

7.1.2 The provenness of overall nuclear power plant systems should be demonstrated through several years of operation of similar nuclear power plants as a commercial plant with a good operational record.

7.1.3 The provenness of the elements as defined in 7.1.1 should be demonstrated through one or more of the following:
Several years of operation in existing nuclear power plant;
Full or part scale testing facilities;
Several years of operation in other applicable industries such as fossil power and process industries.

7.1.4 The supplier should review existing databases of operating experience to identify both positive experience as well as causes of significant events and unplanned outages, and incorporate appropriate features in the nuclear power plant design.

7.1.5 The reactor system should have been licensed or should be licensable in the country of system origin and the licensing information should be made available.

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Performance of Reference Plant

- **IAEA NP-T-2.1, 7.1.2**
  - The provenness of overall nuclear power plant systems should be demonstrated through **several years of operation of similar nuclear power plants as a commercial plant with a good operational record.**
- **EU-APR**
  - The reference plant, SKN #3, has been operated without any transient such as unplanned trip after entering commercial operation on Feb. 2017
  - Other APR1400 constructions are successfully performed in Korea and UAE
- **APR1000**
  - The reference plant, SWN #2, has been operated without any operation problem after entering commercial operation on Jul. 2015
  - 12 OPR1400 plants are operated with greater than 85% of availability

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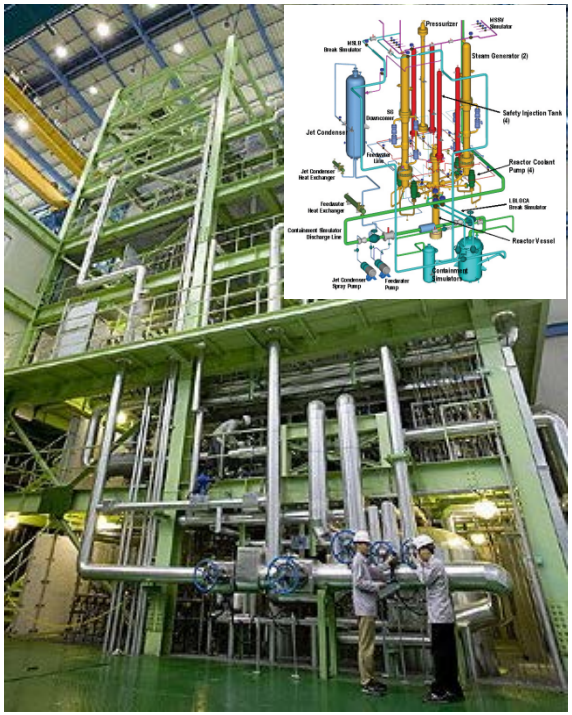
Verification Tests for Newly Adopted Designs

- **IAEA NP-T-2.1, 7.1.3**
  - The provenness of the elements as defined in 7.1.1 should be demonstrated through one or more of the following:
    - Several years of operation in existing nuclear power plant;
    - **Full or part scale testing facilities;**
    - Several years of operation in other applicable industries such as fossil power and process industries.

Verification Tests for Safety Injection System

DVI with ECBD



Integral Loop Test (ATLAS)

SIT

ECC Strainer

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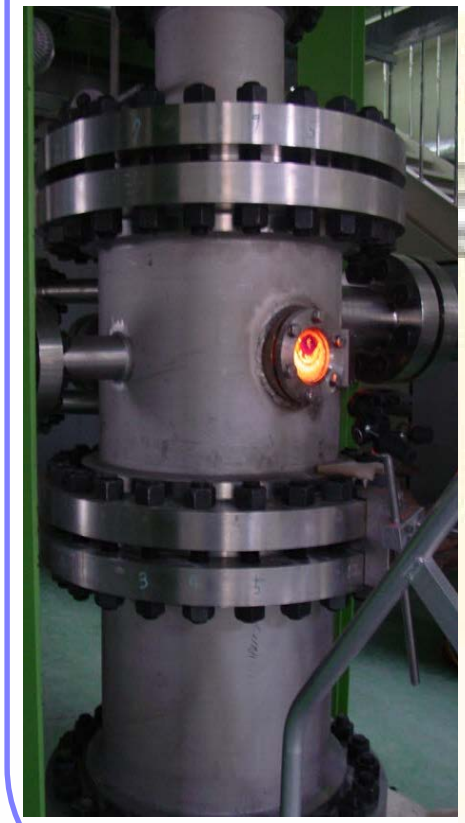
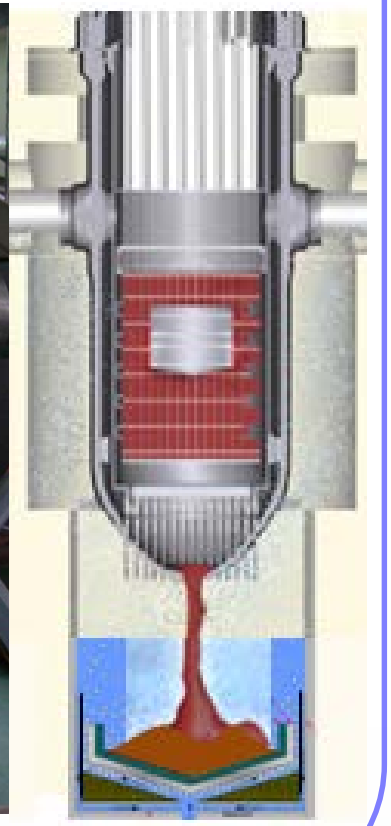
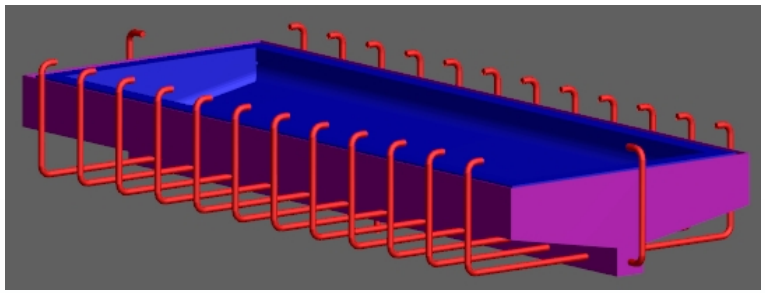
Verification Tests for Core Catcher(PECS)

Corium-Concrete Interaction



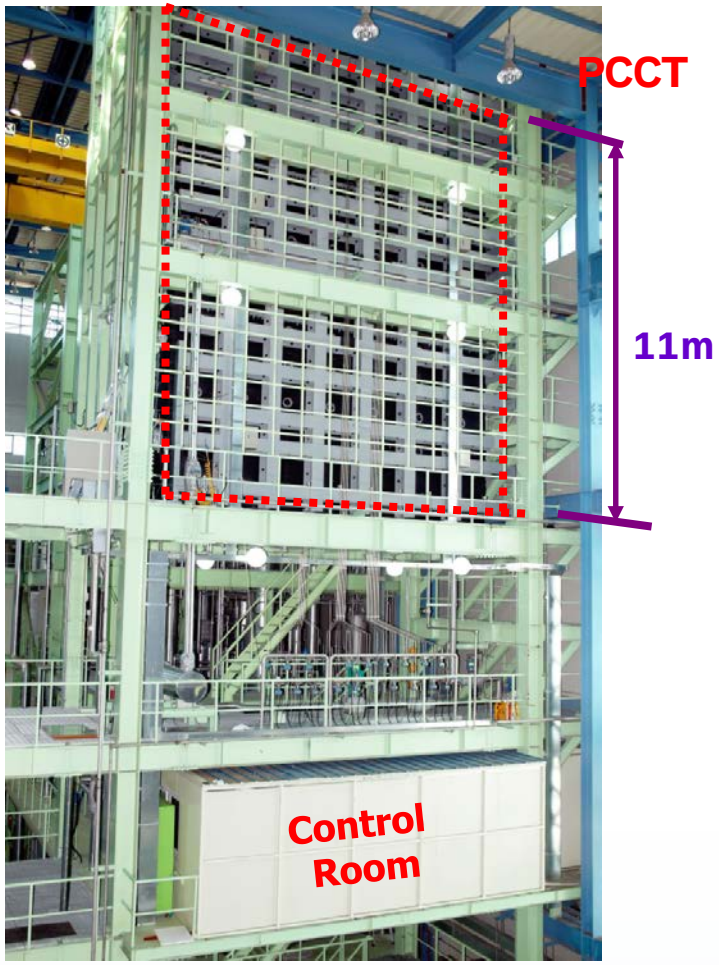


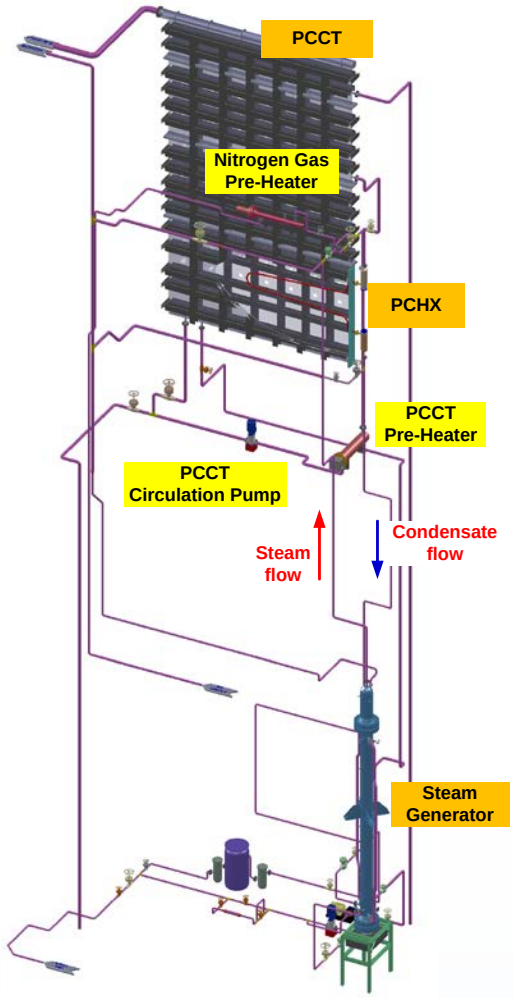
Natural Cooling Capacity



Verification Tests for PAFS

Natural Cooling Capacity





6 Closing Remarks

Closing Remarks

- EU-APR and APR1000 are proven designs to satisfy the customer's demands regarding capacity and applied Codes & Standards
- On-time construction and delivery based on the experience and know-how accumulated through continuous construction and operation of NPPs for the past 40 years
- Technical support through developing advanced technologies to enhance the plant performance
- Continual effort to develop more secure, reliable, and economic advanced reactor

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THANK YOU

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