Proven Technology, Korean APR Reactors for New Build

June. 2022

KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

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Introduction of KHNP

Top 3

Nuclear Utility in the World

KHNP

The Largest Power Generator in Korea

'27%'

Produces 1/3 of Domestic Demand

'28,585MW'

34 Units Construction Experience

26 Units in Operation (24 in Korea and 2 in the UAE)

6 Units under Construction (Including 2 in the UAE)

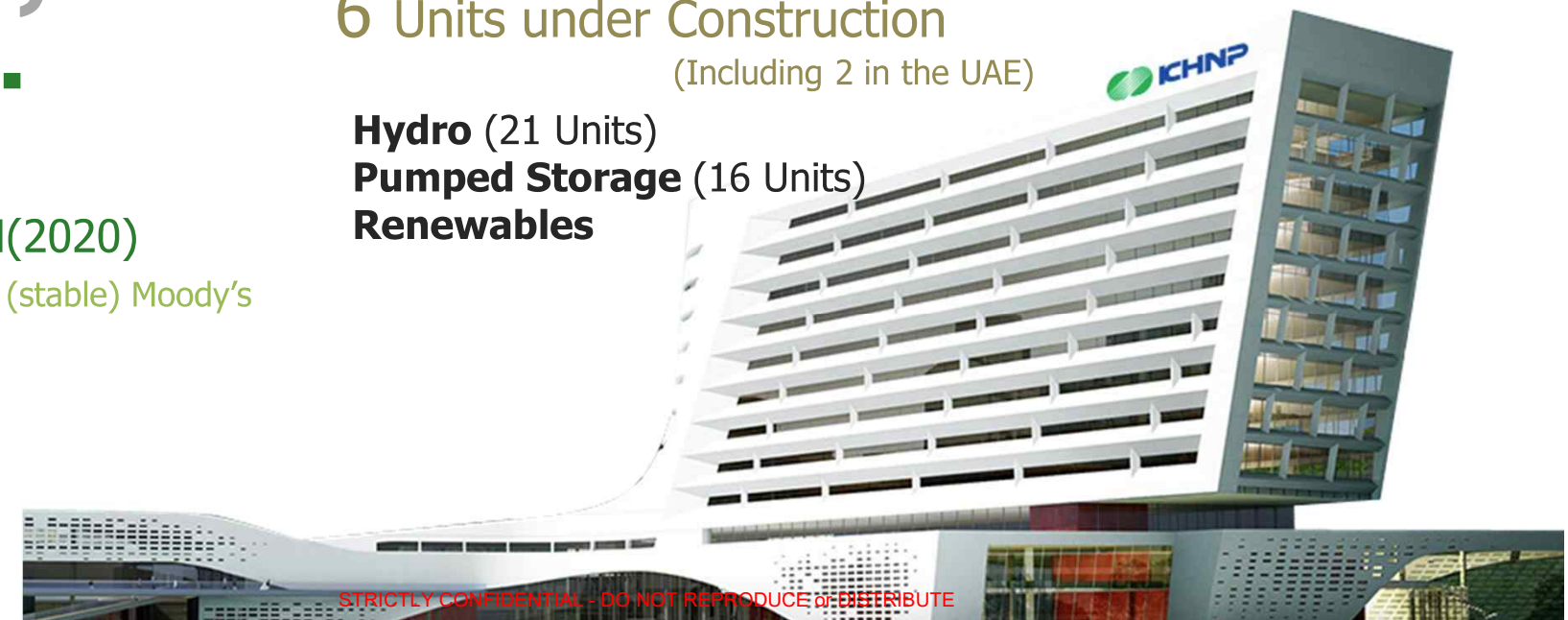
Hydro (21 Units)
Pumped Storage (16 Units)
Renewables

'$54BN.'

Total Asset

Sales : USD 8.5 BN(2020)

Credit rating : Aa2 (stable) Moody's



Nuclear Power Plants in Korea

Operation	24 units	23,250 MW
Construction	4 units	5,600 MW
Permanent Shutdown	2 units	Kori #1 (587 MW) Wolsong #1 (679 MW)

Seoul
Radiation Health Institute

Operation: 6 units
Construction: 2 units

Hanul Site

Daejeon
Central Research Institute

Gyeongju HQ

Operation: 5 units
P. Shutdown: 1 unit

Wolsong Site

Operation: 6 units

Hanbit Site

Kori Site & Saeul Site

Operation: 7 units
Construction: 2 units
P. Shutdown: 1 unit

Busan & Ulsan
KHNP HRD Institute

KHNP

Advanced Reactor Technologies in Korea

Continuous Nuclear Power Plant Construction since 1971

- 24 operating units, 6 units under construction (4 in Korea & 2 in UAE)

Development of GEN III+ reactors for domestic/overseas projects

- Technology advancement, independence and renovation

Introduction of Nuclear Power

- Turnkey
- Kori 1&2

Promotion of Localization

- Non-Turnkey
- Kori 3&4 / Hanbit 1&2

Technology Self-reliance

- **OPR1000**
- 12 Units in operation

Technology Advancement

- **APR1400**
- 3 Units in operation
- 7 Units in construction

Technology Renovation

- **APR+, European-APR1400**
  APR1000
- Design Certification in Korea, US and Europe

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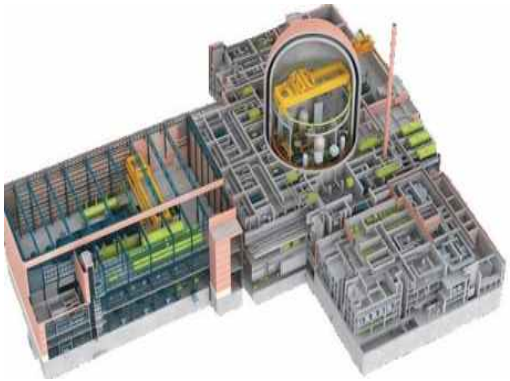
International Design Certification



EU-APR

EUROPEAN UTILITY REQUIREMENTS FOR LWR PLANTS

CEZ • EDF • EDF Energy • EnergoAtom • Fortum • Ingeteam • Gen Energija • Iberdrola • MVM Paks II • NRG • RosEnergoAtom • TVO • Vattenfall • VGB Powertech

The European Utility Requirements (EUR) organisation certifies that the **EU-APR** design has successfully passed all the steps of the analysis of compliance vs. EUR Revision D with the contribution of KHNP, KEPCO E&C, KEPCO NF, and Doosan.

Following this analysis, a specific subset of the EUR volume 3 dedicated to the EU-APR design has been published by the EUR organisation.

November 21st 2017

Guillaume Jacquart, chairman of the EUR Steering Committee

EUR Certification

Issued the EUR Certification for European-APR1400 (Nov. 2017)

US-APR

United States Nuclear Regulatory Commission
Office of New Reactors

The United States Nuclear Regulatory Commission hereby commemorates the issuance of a Standard Design Approval to
Korea Electric Power Corporation
and
Korea Hydro & Nuclear Power Co., LTD
for the

Advanced Power Reactor 1400

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Dated the 28th day of September 2018

Robert M. Taylor, Director
Division of Licensing, Siting, and Environmental Analysis
Office of New Reactors

Frederick D. Brown, Director
Office of New Reactors

US NRC Certification

NRC Certified APR1400 Standard Design (Aug. 2019)

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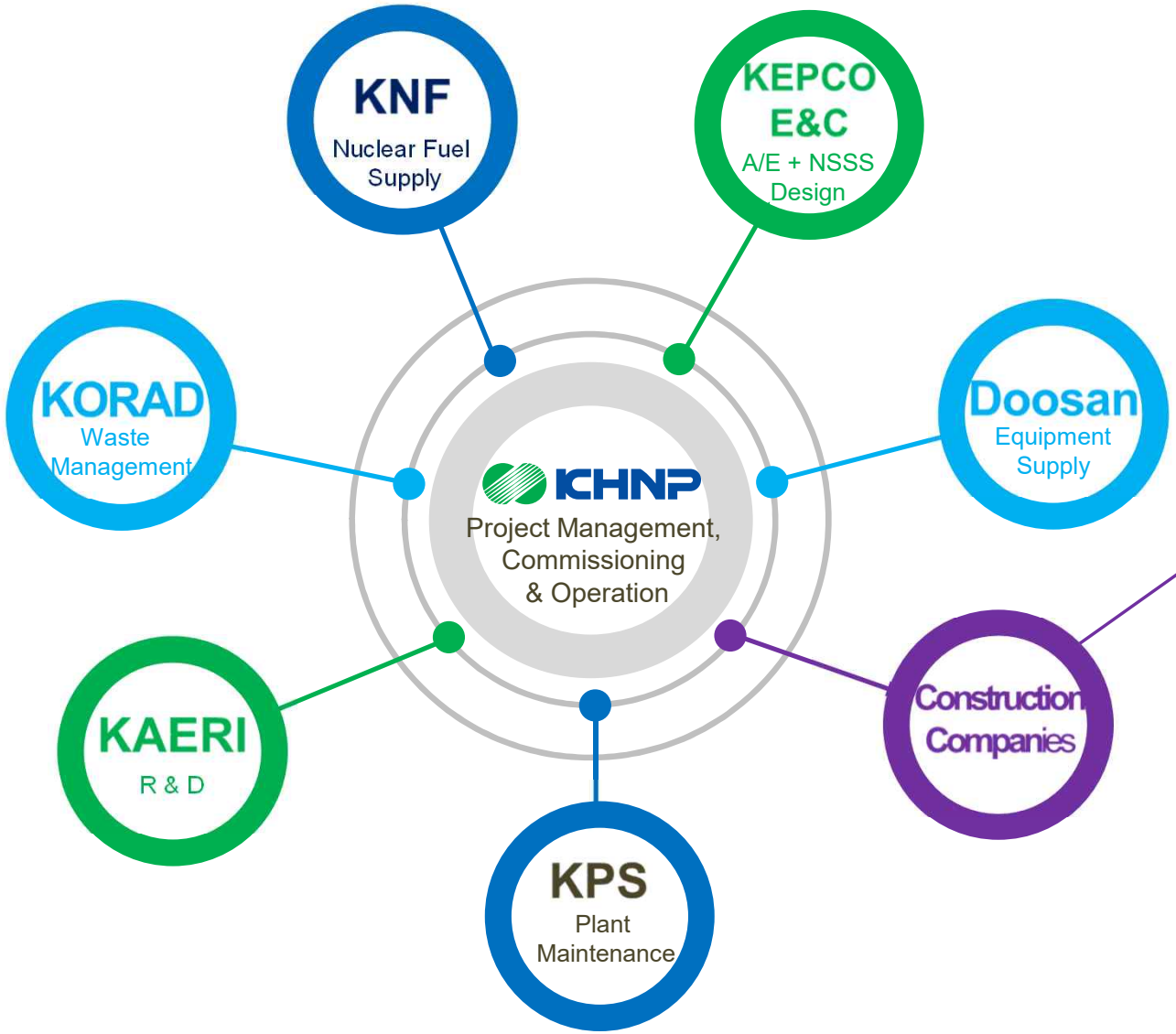
KHNP's Role in Korean Nuclear Industry

The Sole NPP Owner/Operator in Korea



DOOSAN
HYUNDAI ENGINEERING & CONSTRUCTION CO., LTD
GS E&C
SAMSUNG
DAEWOO E&C
DAELIM
Best Value, Better Life
SK E&C

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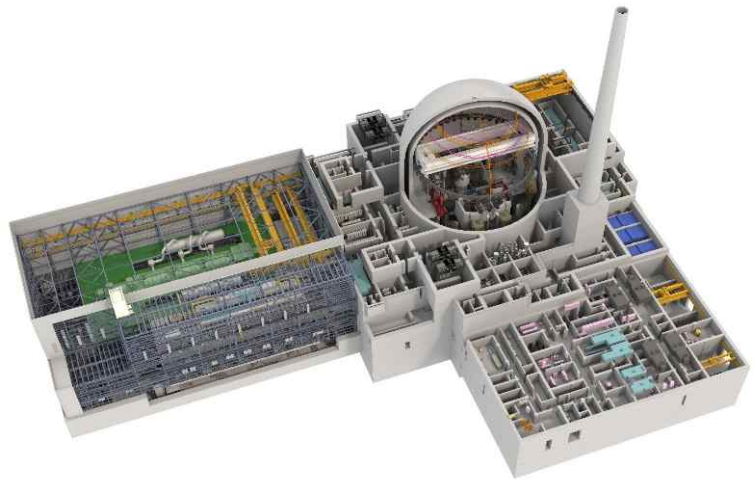
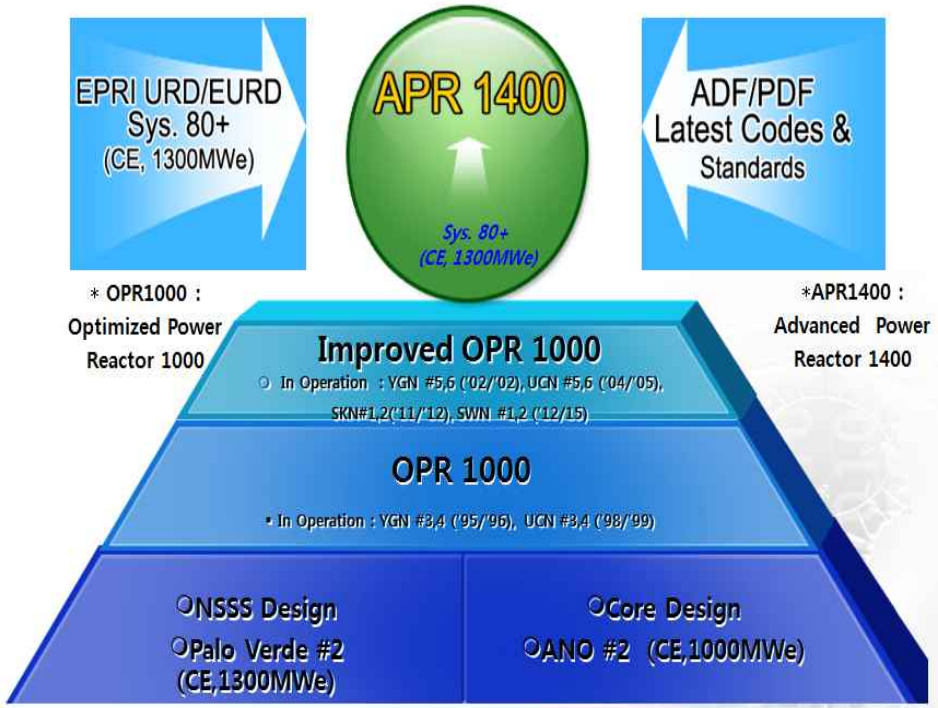
2 APR 1400 Design / Status



Overview of APR 1400

APR1400, the reference plant

- Evolutionary Type ALWR based on OPR1000 and System 80+
- Standard Design Certificate (May 2002) after 10 Years of Development



Overview of APR 1400

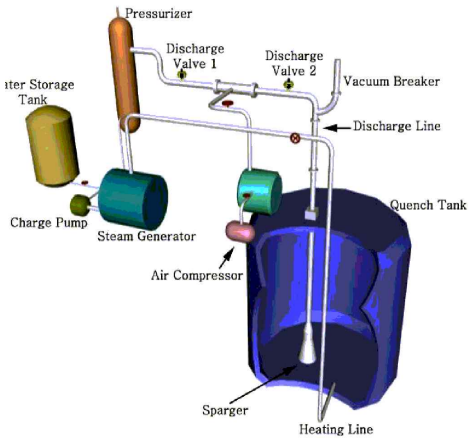
Design Parameters of APR1400

✓ Parameters	APR 1400
▪ **Thermal/ Elec. Power**	**4,000 MWt / 1,450 MWe**
▪ **Design Life**	**60 Years**
▪ **Seismic Acceleration**	**0.3g**
▪ **Operating Parameters**	
- T hot / T cold	**615 / 555 °F**
- Operating Pressure	**2250 psia**
- RCS Flow Rate	**1.66 x 10^6 lb/hr**
▪ **Safety Parameters**	
- CDF	**2.25 x 10^{-6} < 10^{-5} / RY**
- Containment Failure Frequency	**7.19 x 10^{-7} < 10^{-6} / RY**
- Thermal Margin	**> 10%**
- Emergency Core Cooling System	**4-train, DVI, Fluid Device in SIT**
▪ **Performance Requirements**	
- Plant availability	**More than 90 %**
- Unplanned trip	**Less than 0.8 / Year**
- Refueling cycle	**18 ~ 24 months**

APR 1400 Design Features

Proven Design Features of APR1400

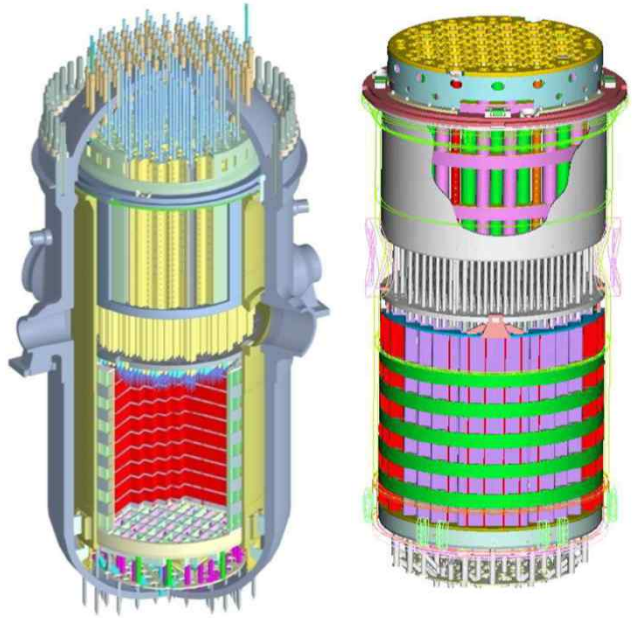
- **Direct Vessel Injection(DVI) with Emergency Cooling Barrel Duct(ECBD)**
  - ✓ Eliminating the Safety Injection water spillage during LB LOCA in cold leg
- **Fluidic Device in Safety Injection Tank (SIT)**
  - ✓ No need of LPSI pumps by regulating the SIT flow passively
- **In-Containment Refueling Water Storage Tank (IRWST)**
- **Fully Digital Man-Machine Interface**



APR 1400 Design Features

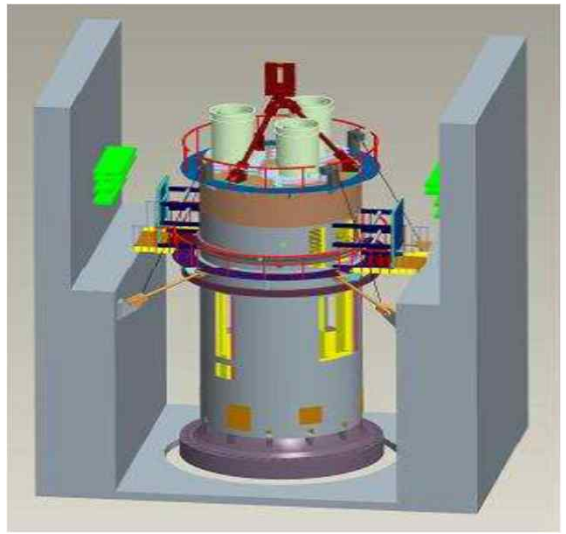
Reactor Vessel & Internal

- ✓ **Enhanced RV integrity**
  - No weld seam in fuel region shell
- ✓ **Reduced radiation exposure**
  - Reduced Cobalt contents in base material
- ✓ **Integrated Inner Barrel Assembly**
  - Welded IBA to UGS upper flange
- ✓ **Integrated Lower Internal Assembly**
  - Integrated core support barrel, core shroud, and lower support structure in one assembly



Integrated Head Assembly (IHA)

- ✓ **Integrated Components**
  - Head area cable tray system, CEDM air handling unit, cooling duct, cooling manifold and head lift rig, etc.
- ✓ **IHA Reduces**
  - Welded IBA to UGS upper flange
  - Eliminate tie rod, round nuts, snubber Flange



APR 1400 Design Features

Steam Generator

✓ Design Parameters

- Integral Economizer
- Number of tubes : 13,102 / SG
- Plugging margin / Tube material : 10 % / Inconel 690

✓ Improved Tube Support Bars and Plate

- Increased anti-vibration bars

✓ Modified SG Inlet Nozzle Angle

- Welded IBA to UGS upper flange

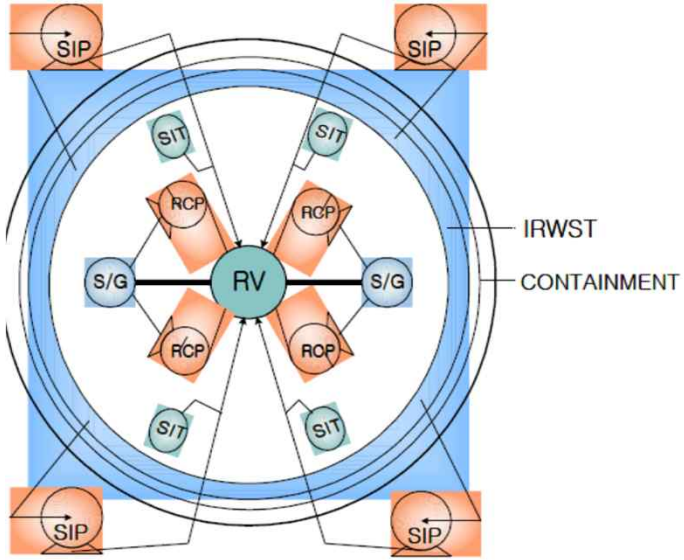
Safety Injection System

✓ Simplified Design

- Mechanically independent 4 train
- 1 SIP / train 1 SIT / train
- No low pressure pumps / One injection mode

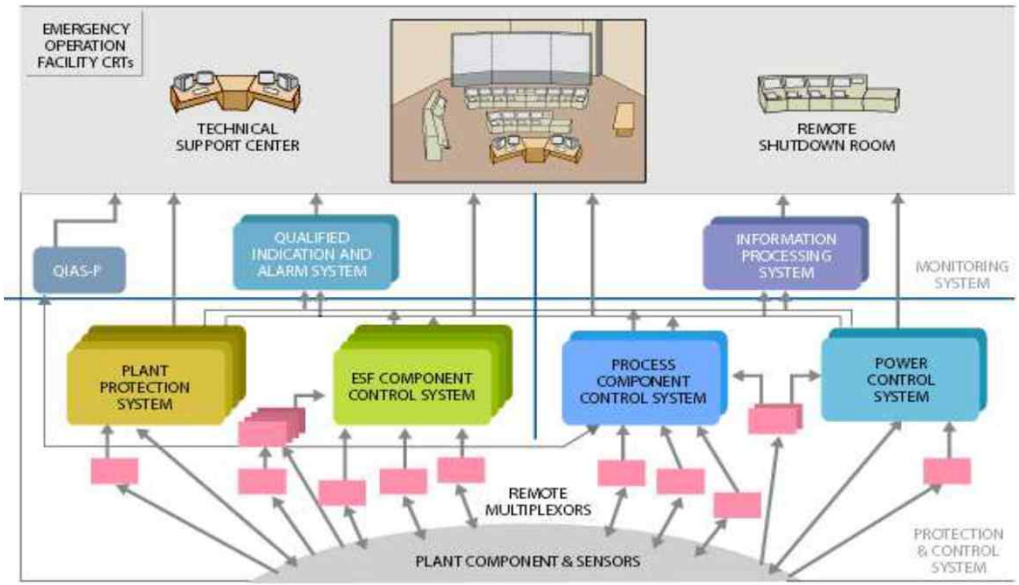
✓ Direct Vessel Injection

- No safety injection water spillage in CL break LOCA
- Increase the reliability of the injection during LOCA



APR 1400 Design Features

MMIS (Man Machine Interface Sys.) Overview



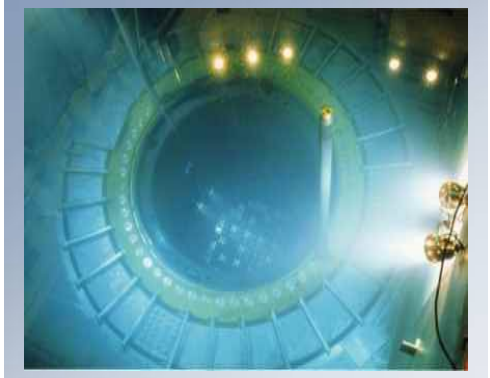
✓ Design Parameters

- Redundant compact workstation with soft control
- Large display panel
- Advanced alarm system
- Safety console (Backup for common mode failure)
- Computerized procedure system

Status - Barakah Project

Contract Date	Dec. 27, 2009
Owner/Contractor	ENEC / KEPCO
Scope	APR1400 x 4 Units (5,600MW) Nuclear Fuel (3 Cycles) Operating Support Service
Ref. Plant	Shin-Kori 3 & 4 in Korea

APR1400 4 Units



Fuel Supply

Simulator

OSS

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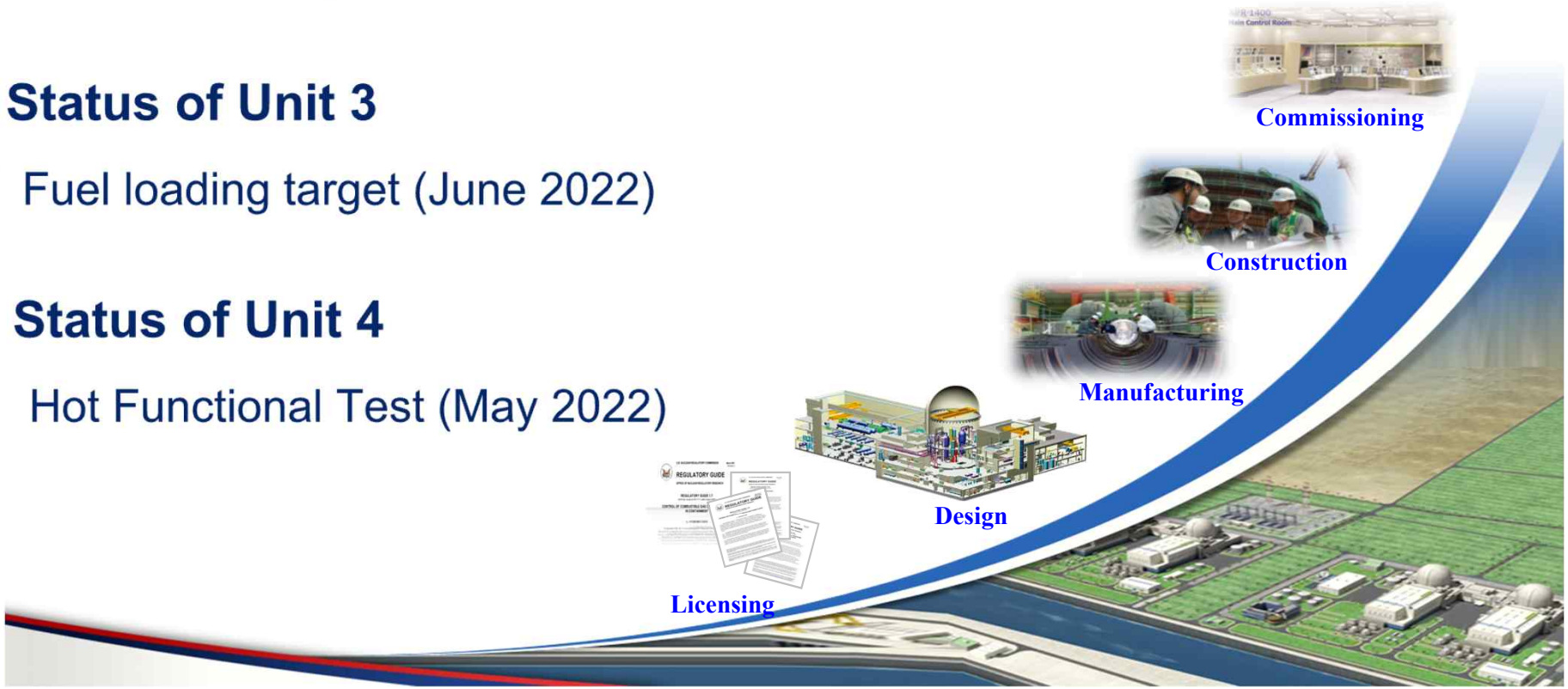
Status - Barakah Project

- **Status of Unit 1 (On-time Delivery)**
  - ✓ **Commercial operation** in April 2021
- **Status of Unit 2 (On-time Delivery)**
  - ✓ **Commercial operation** in March 2022
- **Status of Unit 3**
  - ✓ Fuel loading target (June 2022)
- **Status of Unit 4**
  - ✓ Hot Functional Test (May 2022)



Barakah Project – Midday Break in Summer

UAE Labor Law (Federal Law No. 8 of 1980)

15 June - 15 September 2018
12:00 pm – 3:00 pm

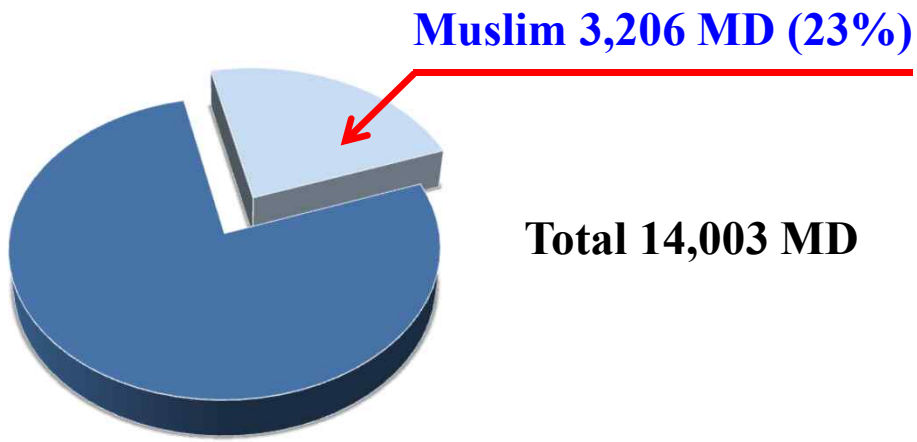
❖ **Working time should be modified for improving productivity and efficiency.**

Description	Site Working Time	Office Working Time
Morning	05:30 ~ 12:00 (6.5 hrs)	06:00 ~ 12:00 (6.0 hrs)
Afternoon	15:00 ~ 18:30 (3.5 hrs)	14:00 ~ 18:00 (4.0 hrs)
Night / Overnight (2 shifts)	19:30 ~ 04:30(+1) (If necessary)	




Barakah Project – Ramadan Month

[12 April ~ 12 May 2021]



Total 14,003 MD

[Muslim & Non Muslim Labor Status]

Working Schedule

Description	Non Muslim's Working Time	Muslim's Working Time
Morning	05:30 ~ 12:00 (6.5 hrs)	05:30 ~ 12:00 (6.5 hrs)
Afternoon	15:00 ~ 18:30 (3.5 hrs)	-
Night / Overnight (2 shifts)	19:30 ~ 04:30(+1) (If necessary)	-

Barakah Project - Dust and Sandstorm

Protection Measures

Microfilament netting

Watering

Tarpaulin Tent

Vinyl Packing

Sand Blockages

Gravel Pavement

Vinyl Packing

Temporary Ventilation

Status - Domestic Construction

Shin Hanul unit 1 & 2

Item	Unit 1	Unit 2	Total	1st Concrete
General	99 %	99 %	99 %	2012.7
Construction	100 %	100 %	100 %	2013.6
Commissioning	85 %	79 %	83 %	

- **Unit 1** : Completion of HFT / Operation License (’21.7)
- **Unit 2** : Commissioning (Pre-service inspection) / Operation License (’22.12)

Shin Kori unit 5 & 6

Item	Unit 1	Unit 2	Total	1st Concrete
General	86 %	67 %	78 %	2017.4
Construction	83 %	53 %	73 %	2018.9
Commissioning	17 %	0%	16.78 %	

- **Unit 5** : Under construction / CHT (’23.6)
- **Unit 6** : Under construction / Initial Power Energization (’22.12)

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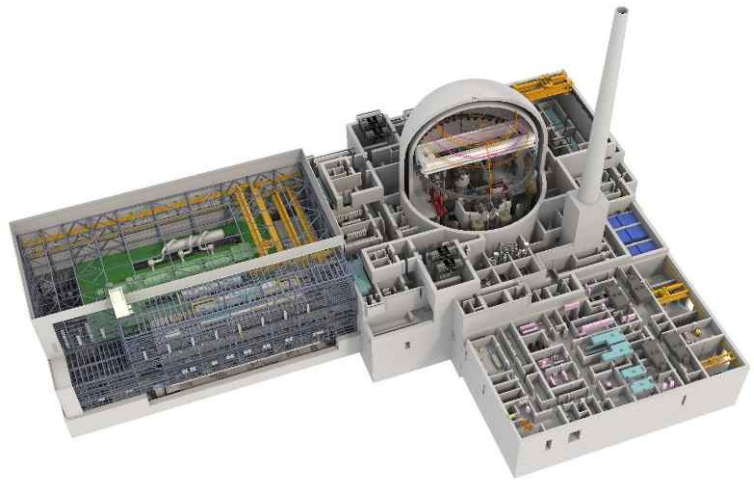
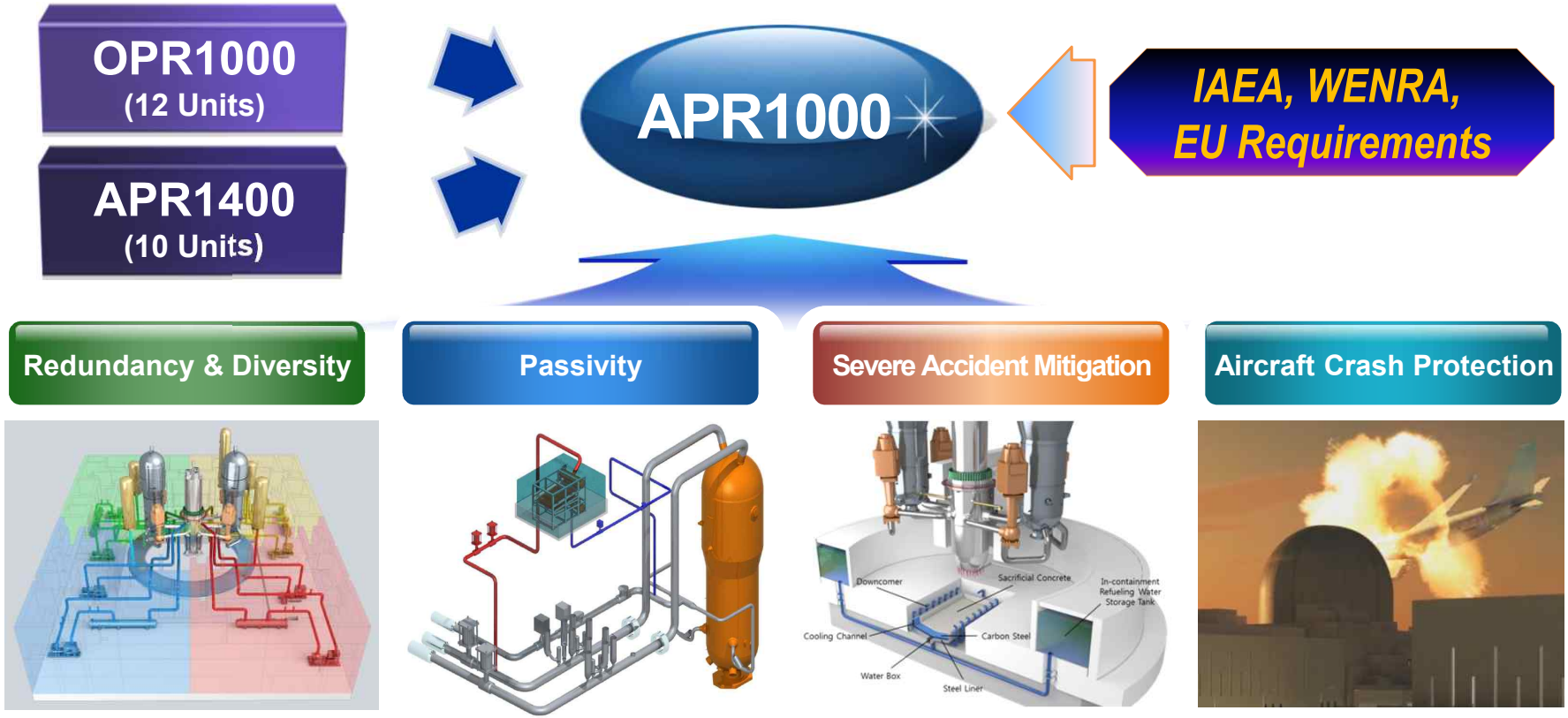
3 APR 1000 Design



Overview of APR 1000

Mid-size GEN III+ Pressurized Water Reactor

- Accumulated experience in the construction and the operation of a large fleet of NPPs
- Safety enhancement reflecting up-to-date IAEA, WENRA and European requirements
- Customized for nuclear new-build in European countries



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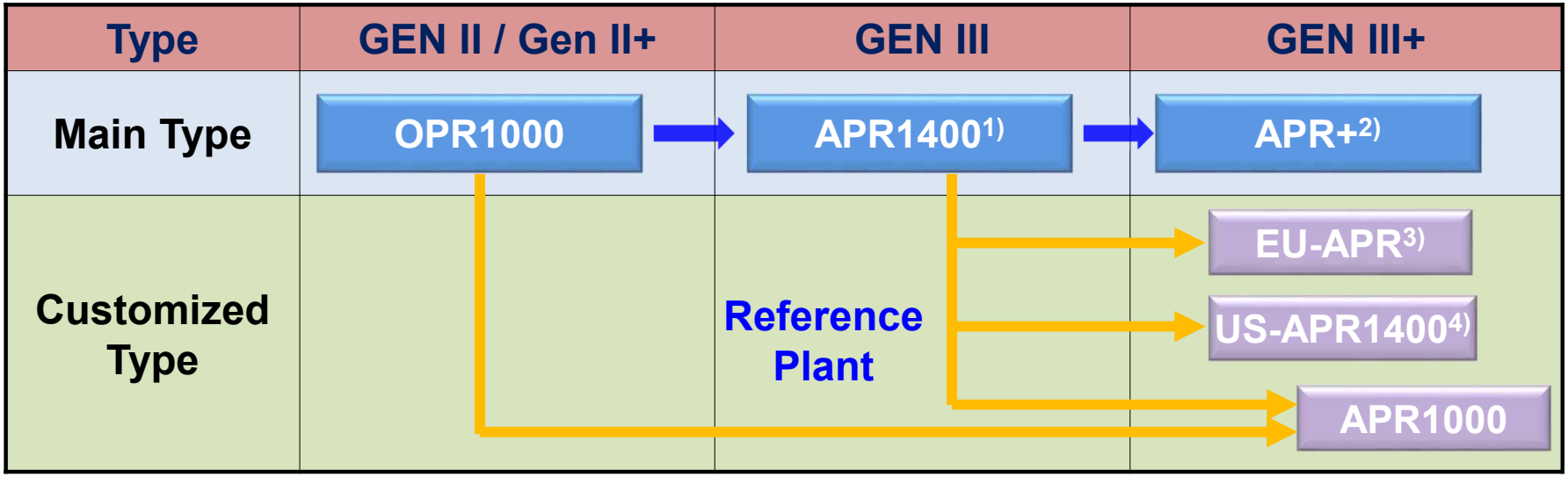
Strategy for GEN III+ Reactor Developments

Main Type

- Development of evolutionary reactors to enhance safety
- Demonstrating performance through domestic construction and operation

Customized Type

- Adaptation to regulations and utility demands in customer country
- Providing good licensibility with proven technology



1) APR1400: SDA in 2002 by Korean NSSC
2) APR+: SDA in 2014 by Korean NSSC
3) EU-APR: Certificate in 2017 by EUR
4) US-APR1400: SDA in 2018 by US NRC

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Overview of EU-APR

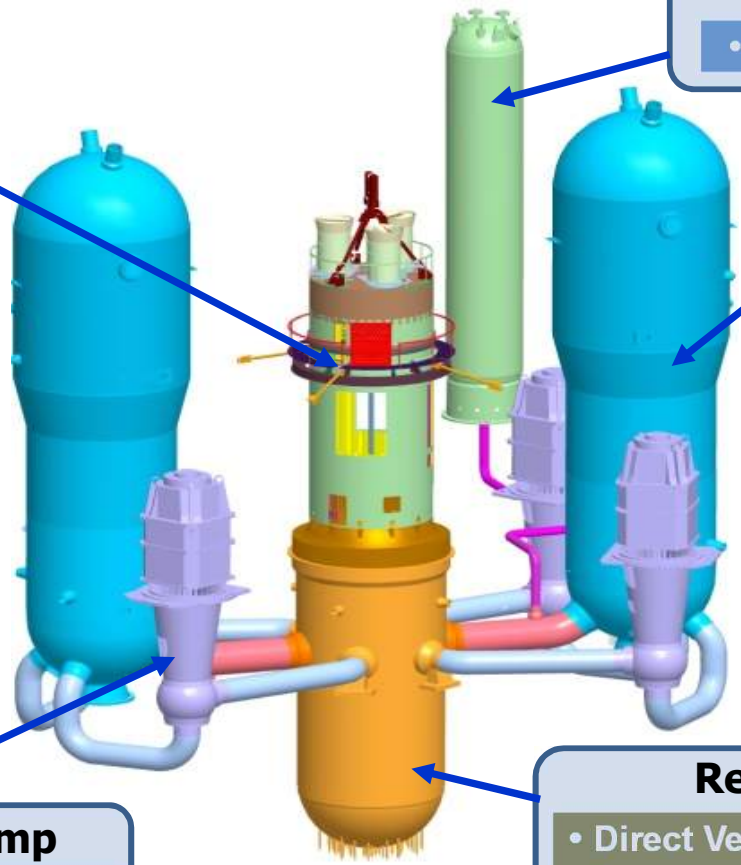
Comparison of EU-APR

Parameters	EU-APR	APR1000
Design Criteria Base	IAEA, WENRA, EUR	IAEA, WENRA, EUR
NSSS Core Thermal Power	3983 MW	**2815 MW**
Number of FA	241	**177**
Fuel	PLUS7	**HIPER16**
Turbine & Generator	1800 rpm, 50 Hz	**3000 rpm, 50 Hz**
Ultimate Heat Sink	Sea water	**Atmosphere (Cooling Tower or Pond)**
Engineered Safety Features	Mech. 4-Train with Elec. 4-Train	Mech. 4-Train or 2-Train with Elec. 4-Train
Diverse Safety Features	Diverse Protection System Emergency Boration System Dedicated Safety Systems	Diverse Protection System Emergency Boration System Dedicated Safety Systems
Emergency S/G Cooling	Active	Passive
Corium Cooling during Severe Accident	Core Catcher	Core Catcher
I&C Design	Fully Digital, 3-platform	Fully Digital, 3-platform
Containment Structure	Double (PSC with liner and RC)	Double (PSC with liner and RC)

Major Characteristics (1/4)

Reactor Coolant System

- Simple configuration with 2-loop
- Extensive operating experience
- 60-year design life



Pressurizer
• Large Free Volume

Integrated Head Assembly
• Maintainability

Steam Generator
• 10% Plugging Margin

Reactor Coolant Pump
• 1490 rpm for 50 Hz Electricity

Reactor Vessel
• Direct Vessel Injection with Emergency Core Cooling Barrel Duct

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Major Characteristics (2/4)

Full four train safety systems

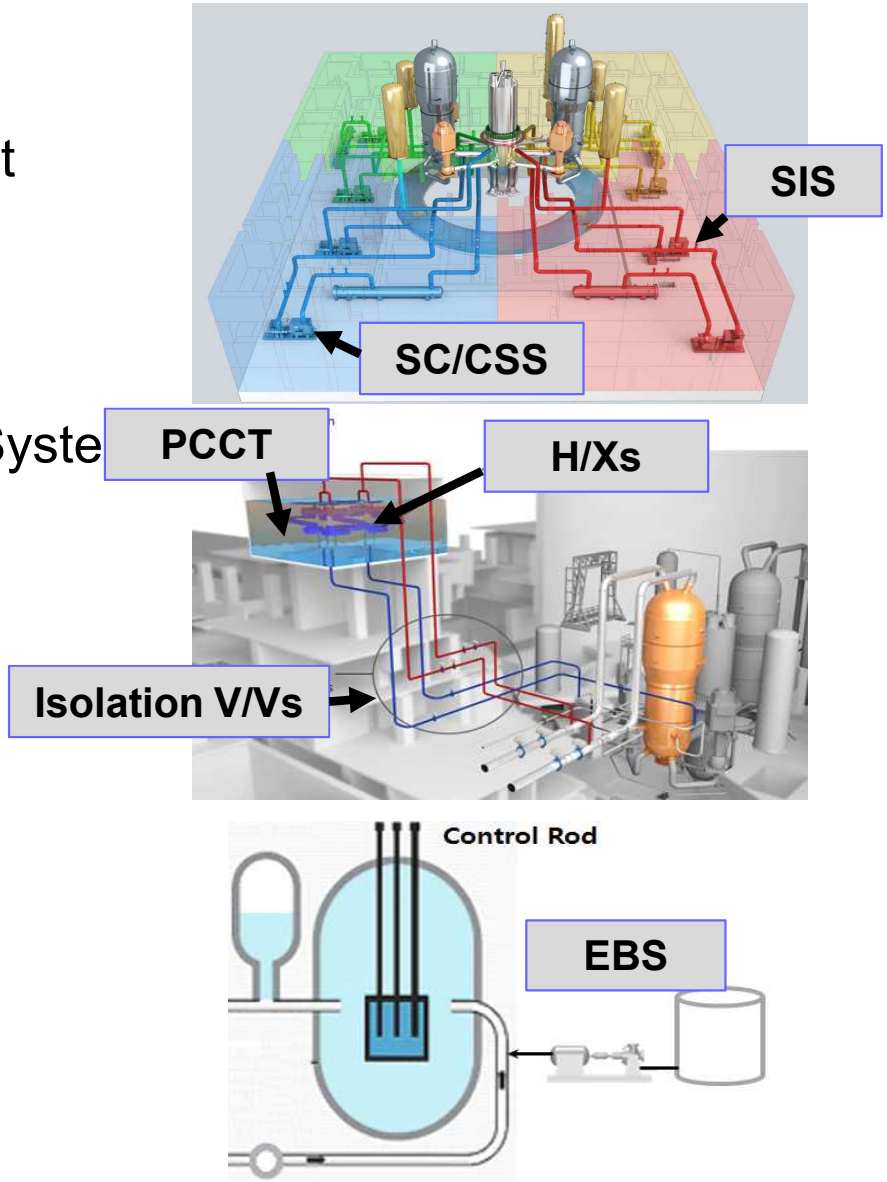
- Safety systems for design basis accident
- Safety Injection System (SIS)

  (Direct Vessel Injection, Fluidic Device)
- Shutdown Cooling/Containment Spray Syste

  (SC/CSS)

Two independent Passive Auxiliary Feedwater System (PAFS)

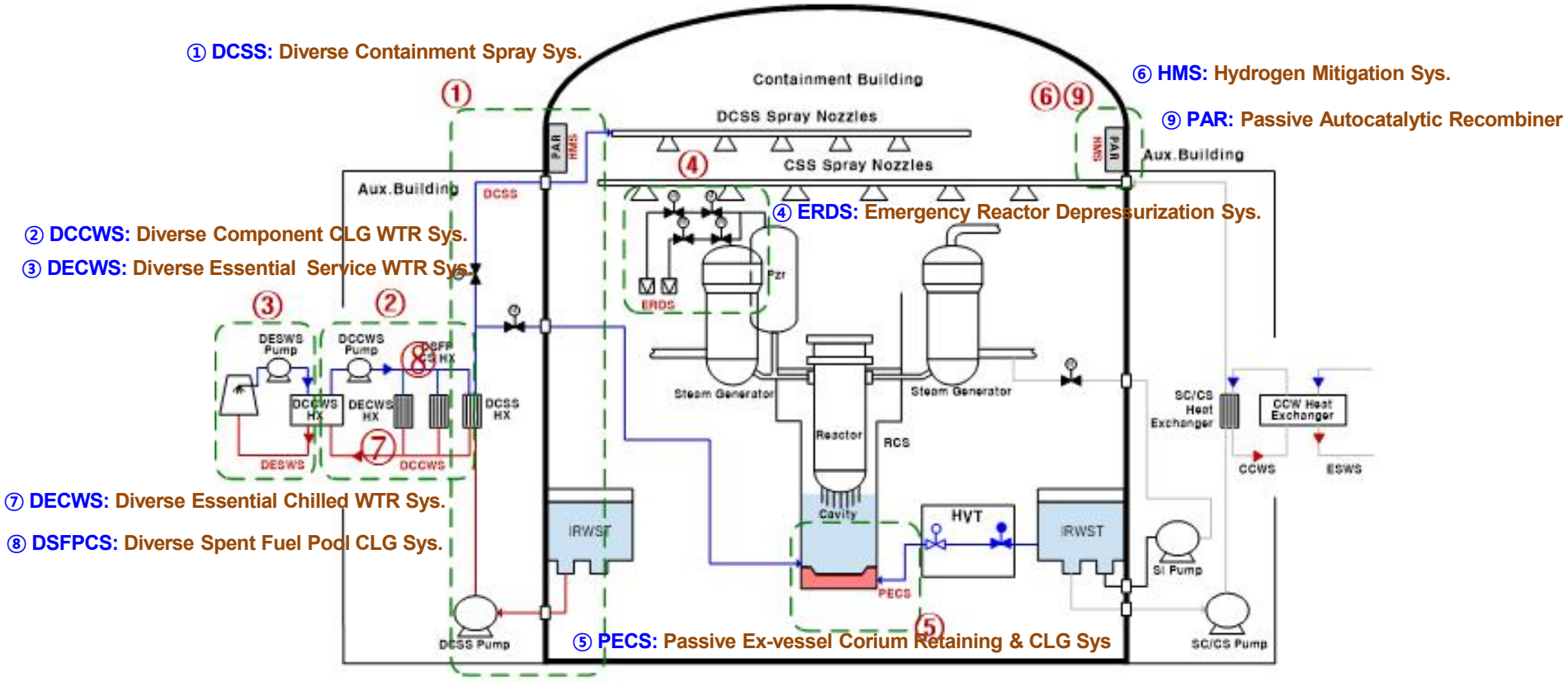
- Removes decay heat to reach shutdown cooling entry condition
- Increase coping capability for SBO



Major Characteristics (3/4)

Diverse Safety Features

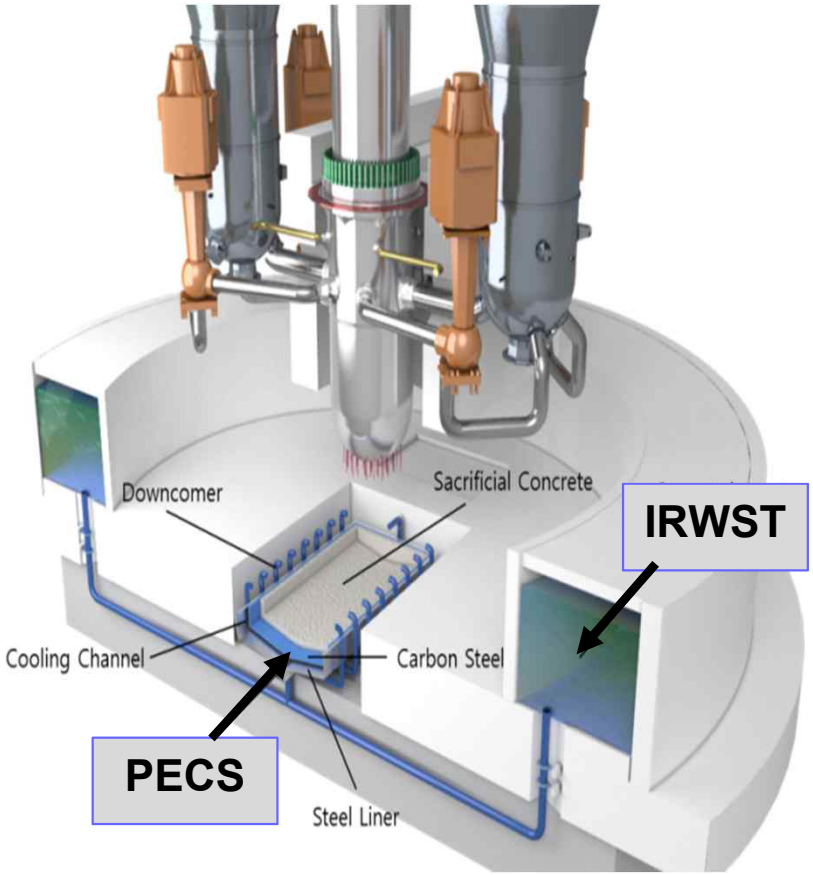
- Dedicated systems for design extended condition and severe accident mitigations
- Physically and functionally separated from DBA safety systems
- Improve coping capability of common caused failures
- DCSS, DCCWS, DESWS, DSFPCS, etc.



Major Characteristics (4/4)

Severe Accident Management

- Dedicated SA mitigation systems
  - ✓ Emergency reactor depressurization
  - ✓ Ex-vessel corium retaining and cooling
  - ✓ Hydrogen re-combiners
- Practical Elimination
  - ✓ Direct Containment Heating (DCH)
  - ✓ High Pressure Melt Ejection (HPME)
  - ✓ Basemat melt-through
  - ✓ Steam explosion
  - ✓ Hydrogen combustion
  - ✓ Containment over-pressurization, etc.

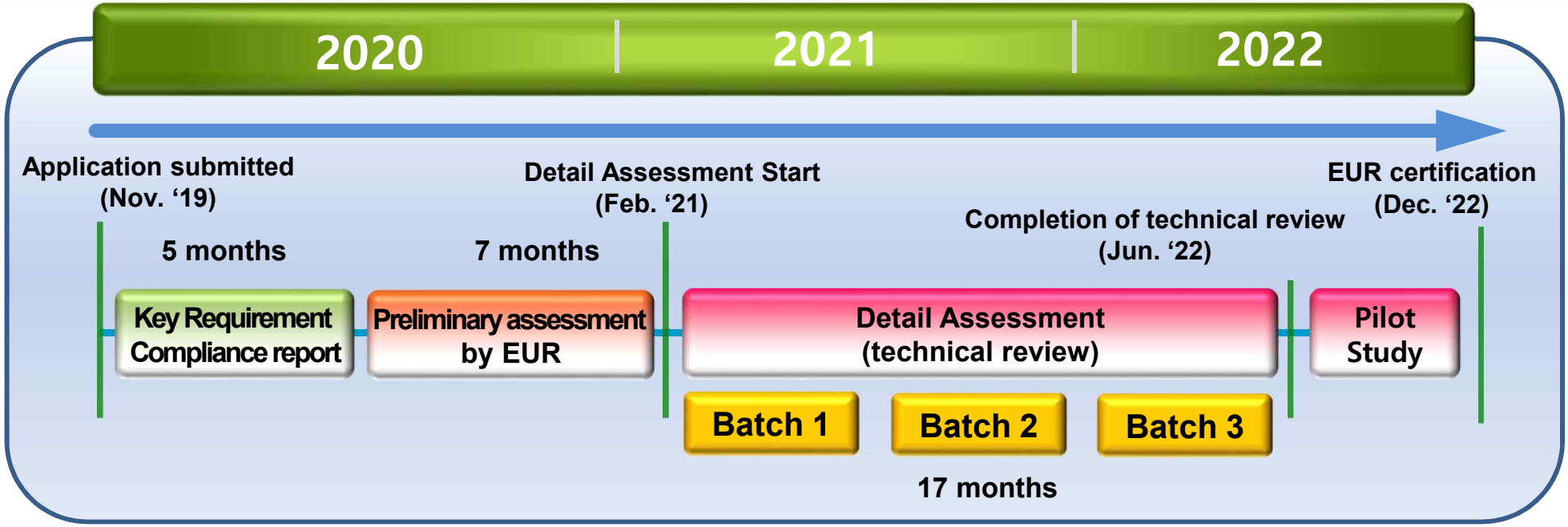


4 EUR Assessment Plan & Progress

APR1000 EUR Assessment Plan & Progress

- **(Nov. 2019) Submittal of the Application of APR1000 EUR Certification**
- **(Mar. 2020) Confirmation on assessment start by EUR organization**
  - Sponsors (3): CEZ, Tractebel, Fortum
  - Supporters (3): EDF, Energoatom, GEN Energija
- **(Jan. 2021) Completion of Preliminary Assessment (53 key issues)**
- **(Feb. 2021) Start of Detailed Assessment (20 chapters)**
  - BATCH 1 (7 Chapters, 100%) BATCH 2 (6 Chapters, 80%)
  - BATCH 3 (7 Chapters, 70%)
- **(May. 2022) Completion of 8 CG** (Coordination Group) **/ 12 CG**

APR1000 EUR Assessment Plan & Progress



- Standard design of APR1000 is under detail assessment based on EUR (Rev.E)
- Batch 1 self-assessments and design documents are under review with coordination group meetings (8th CG meeting is completed) * CG: Coordination Group
- Batch 2 self-assessments and design documents are submitted to EUR
- No schedule delay and on time review completion is expected
- Review results will be incorporated into the improvement of APR1000 design

5 Conclusion

Closing Remarks

EU-APR 1400 / APR 1000

- ✓ Uses proven design technologies
- ✓ Reflects accumulated operating experiences
- ✓ Adopts advanced design features
- ✓ Incorporates the state-of-art safety requirements

KHNP has

- ✓ Outstanding construction, PM / QM and Engineering capabilities
- ✓ TEAM Korea provides robust supply chains and abundant experience
- ✓ Licensing competitiveness
- ✓ Experience in the proven technology of APR 1400 (BNPP Project & Korean Npps) and confidence in the successful completion of European APR reactor projects.

THANK YOU

Sebin CHEON (nicebinny75@khnp.co.kr)