Regulatory Framework, Standards and Issues for Site Evaluation in Korea

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CONTENTS

1. Nuclear Power Plants in Korea (1/3)

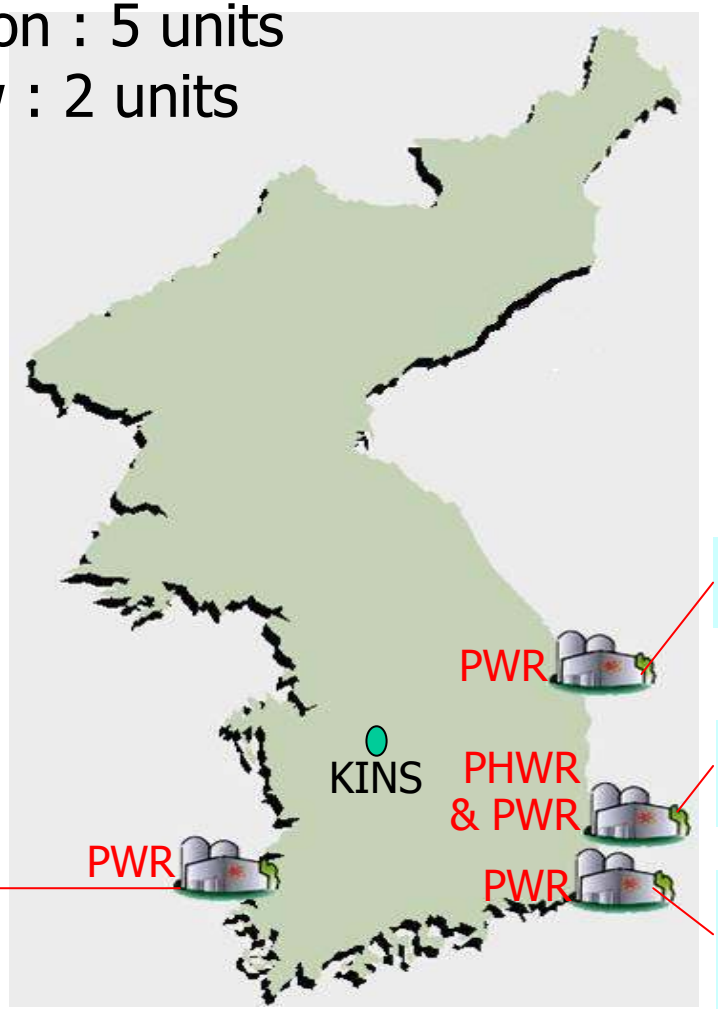
- Current status of NPPs in Korea
  - Korea has achieved a remarkable growth in nuclear power since commercial operation of Kori Unit 1 in 1978
  - Korea has now 21 operating NPPs : 17 PWRs and 4 PHWRs
    - Total output of 21 licensed units is 18,716 MWe
      - **generation capacity : 24.8% (2010.12)**
      - **actual production : 31.4 % (2010)**
  - 5 PWRs (5,800 MWe) are now under construction and 2 PWRs (2,800 Mwe) are under the safety review for CP
  - Total units in operation by 2016 : 28 units

1. Nuclear Power Plants in Korea (2/3)

◎In operation : 21 units

◆Under Construction : 5 units

■ Under CP Review : 2 units



◎ Ulchin 1, 2, 3, 4, 5, 6
■ Shin-Ulchin 1, 2

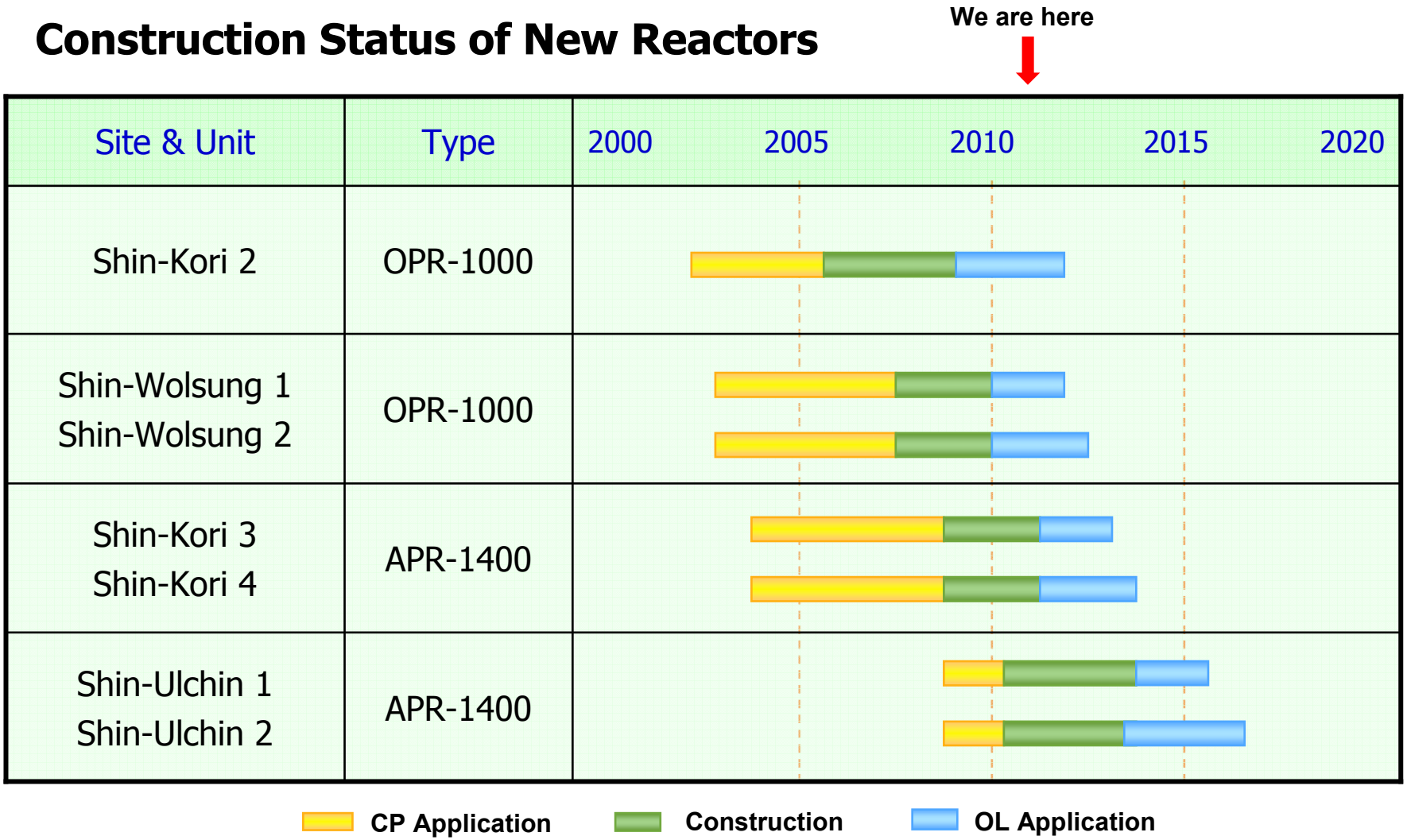
◎ Wolsong 1, 2, 3, 4
◆ Shin-Wolsong 1, 2

◎ Yonggwang 1, 2, 3, 4, 5, 6

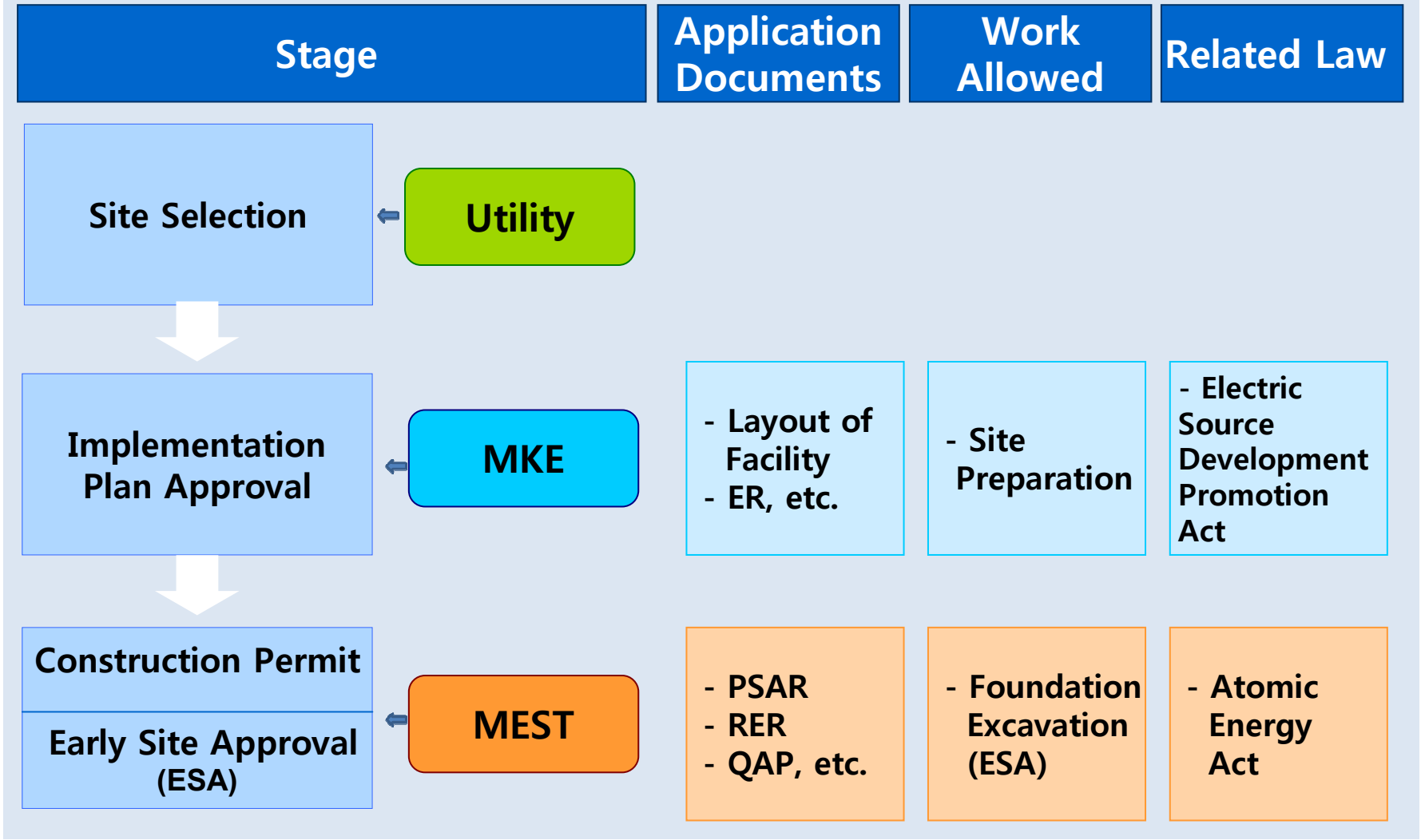
◎ Kori 1, 2, 3, 4, Shin-Kori 1
◆ Shin-Kori 2, 3, 4

1. Nuclear Power Plants in Korea (3/3)

Construction Status of New Reactors



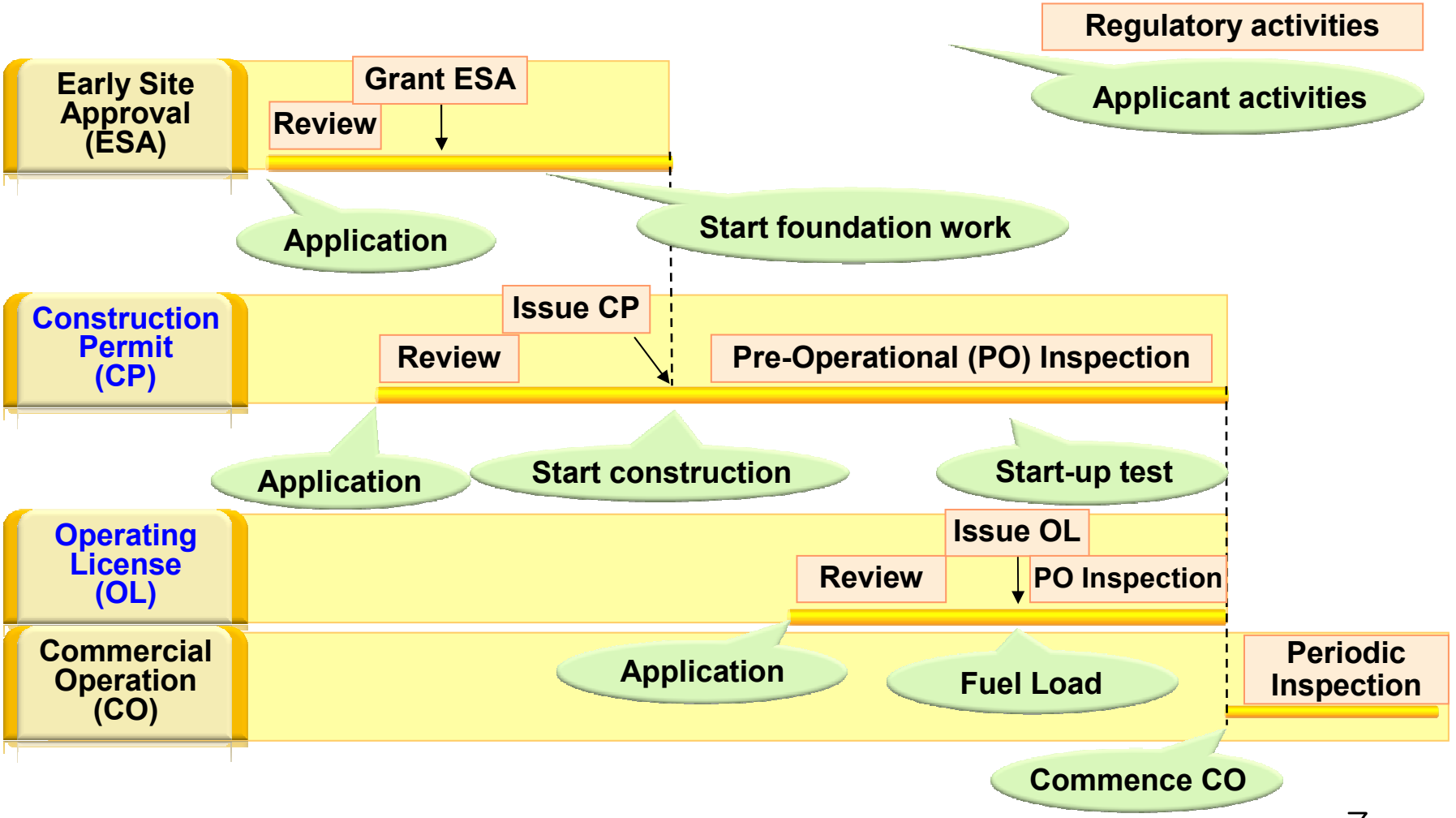
2. Licensing Process for New Reactors (1/3)



MKE (Ministry of Knowledge Economy), MEST (Ministry of Education, Science and Technology)
ER (Environmental Report), RER (Radiological Environmental Report), QAP (Quality Assurance Program)

2. Licensing Process for New Reactors (2/3)

Overall Licensing Process



2. Licensing Process for New Reactors (3/3)

Construction Permit (CP)

- To ensure the plant design adequacy in accordance with Rules and Regulations, prior to the commencement of construction
- Major application documents
  - Preliminary Safety Analysis Report (PSAR), Quality Assurance Program (QAP) for design and construction, Radiological Environmental Report (RER), etc.

Early Site Approval (ESA)

- To allow the applicant to perform a limited civil engineering work such as power block excavation, before CP
- Application documents: Site Survey Report, Radiological Environmental Report, etc.

3. Regulatory Framework (1/4)

MEST

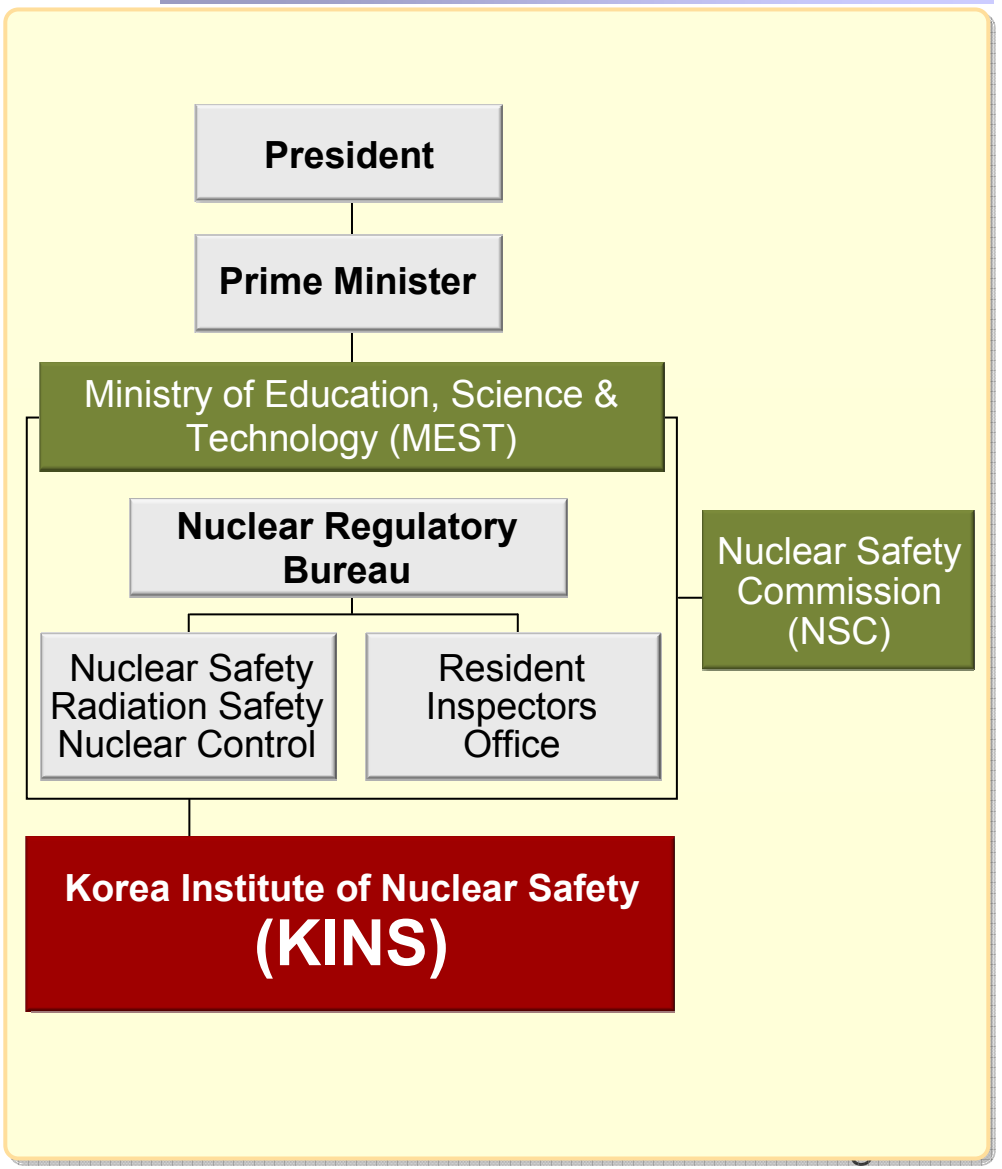
- Regulatory enforcement authority

NSC

- National top-level decision -making organization
- Decision-making on major nuclear issues

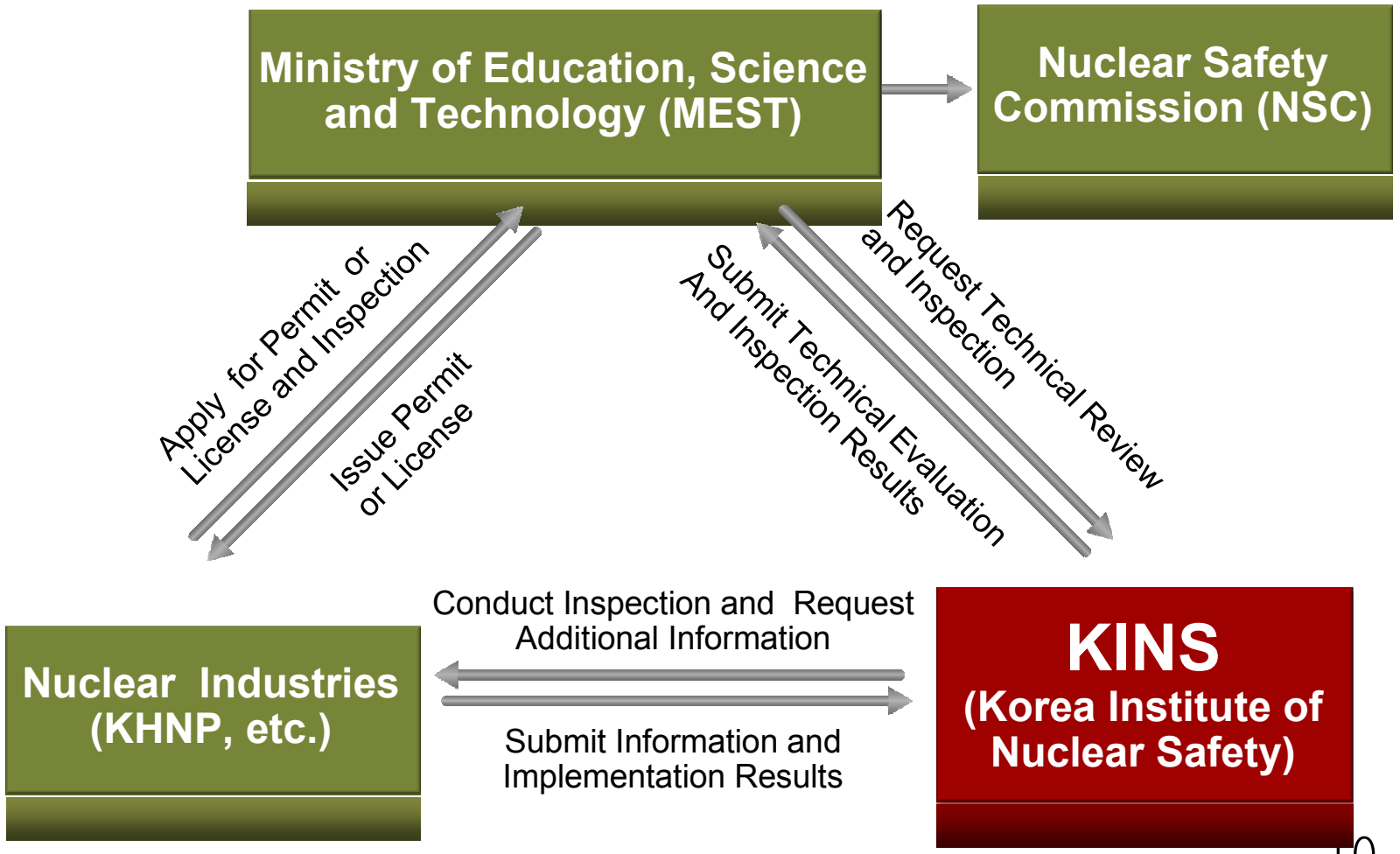
KINS

- Regulatory agency having expertise
- Entirely dedicated to nuclear safety regulation



3. Regulatory Framework (2/4)

Interactive Mechanism in Regulation



3. Regulatory Framework (3/4)

KINS Mission

Protection of the public health and safety and the environment from potential radiation hazards accompanied by the utilization of nuclear energy

Nuclear safety review based on objectivity and fairness

Key Services

- Nuclear Safety Regulation
- Radiation Safety Regulation
- Environmental Monitoring
- Radiological Emergency Preparedness
- Development of safety standards, criteria and regulatory technologies
- Establishment of technology bases for regulating nuclear & radiation safety

3. Regulatory Framework (4/4)

KINS Facilities

Headquarter

R & D Center

International Nuclear Safety School

Emergency Center

Central Monitoring Station

Temporary Orphan Source Storage

4. Legal System and Technical Standards (1/2)

Law	Articles 12 (Acceptance Criteria for Construction Permit), 22 (Acceptance Criteria for Operating License) & 96 (Exclusion Area) of AEA
Ordinance of the Minister of Education, Science and Technology (MEST)	Article 4 (Geology & Earthquake) of "Enforcement Regulations concerning the Technical Standards of Reactor Facilities, etc." • Nuclear facilities should be located in a stable region at a minimal adverse effect from earthquakes & tectonic disruptions • Nuclear facilities should be located on a stable geological foundation without ground subsidence Articles 5 (Site Limitation), 6 (Meteorology), 7 (Hydrology & Marine Environments), 8 (Human Induced Incidents), etc.
Notice of the MEST	● No. 2009-37, "Technical Standards for Locations of Nuclear Reactor Facilities" • Technical Applications: 10CFR 100.11, 10CFR Part 100 App. A, R.G. 1.60, etc. ● No. 2009-37, "Technical Standards for Meteorological Evaluations for the Reactor Facility Site" ● No. 2009-37, "Technical Standards for Hydrology and Marin Environment Evaluation for the Reactor Facility Site"
Review Guidance	▪ KINS/GE-001, 2009, Safety Review Guideline (SRG) for PWR (Chapter 2. Site)

4. Legal System and Technical Standards (2/2)

Technical Standards applied to MEST Notice No. 2009-37

No.	Subjects	Articles	Technical Standards applied accordingly
1	Guidelines for investigating and evaluating seismic and geologic characteristics of nuclear reactor facilities site	Regulations Article 4	● 10CFR Part 100 Appendix A : "Seismic and Geologic Siting Criteria for Nuclear Power Plants " ● R.G. 1.60: "Design Response Spectra for Seismic Design of Nuclear Power Plants " ● R.G. 1.132: "Site Investigations for Foundations of Nuclear Power Plants " ● R.G. 1.138: "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants"
2	Guidelines for location restrictions of nuclear reactor facilities	Regulations Article 5	● 10CFR 100.11: "Determination of Exclusion Area, Low Population Zone and Population Center Distance"
3	Guidelines for investigating and evaluating man-made incidents for site selection	Regulations Article 8	● R.G. 1.78: "Assumptions for Evaluating the Habitability of Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release " ● R.G. 1.91: "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants " ● R.G. 1.95: "Protection of Nuclear Power Plant Control Room Operators against an Accidental Chlorine Release"

5. Major Regulatory Criteria under Review for Revision

- Definition of the Capable Fault
- Extent of Site Investigation
- Seismic Monitoring in the New Reactor Site
- PSHA Requirement
- Population Center Distance Requirement

Definition of the Capable Fault

- Background
  - ✓ Long term research for the establishment of the Korean-specific definition for a capable fault was performed
    - 10 CFR 100, App. A "Seismic and Geologic Siting Criteria for Nuclear Power Plants, 1973"
    - Different definition is used in IAEA, US, Japan, China, etc.
- Revision Direction
  - ✓ Current : Evidences of one fault movement within the past 35,000 yrs or, recurrent behavior within the past 500,000 yrs
    - Proposed before : Similar to the Japanese one
    - Proposed now: 35,000 yrs → 50,000 yrs (USNRC RG 1.165, 1997)
  - ✓ Additional review on the related technical stuff is under process
    - Introduction of Korean-specific definition is very sensitive issue

Extent of Site Investigation

➢ Background

- ✓ Long term research for establishing the Korean-specific criteria for the extent of regional and site geological investigation was performed
  - Different in IAEA, US, Japan, China, etc.

➢ Revision Direction

- ✓ Four areas defined by circles drawn around the site (more in detail as approaching to reactor site)
- ✓ Reflection of Korean geological and seismological information & data (ex. attenuation characteristics, tectonics)

	Current (10CFR100, App. A)	Revision Direction
Regional Investigation	Radius of 200 mile (320km)	Radius of 200km (1:250,000)
Site Investigation		40km (1:50,000)
	5 mile (8km)	5km (1:25,000)
		1km (1:500)

Seismic Monitoring in the New Reactor Site

- Background
  - ✓ Seismic monitoring in the site area is required before construction
    - To provide more detailed information on potential seismic sources in the site vicinity
- Revision Direction
  - ✓ Monitoring should be initiated as soon as practicable at the site, at least three years prior to the construction,
  - ✓ and should be continued until the free-field strong ground motion monitoring commences
  - ✓ The seismic network should be sensitive enough to locate micro-earthquakes
    - ※ IAEA(NS-G-3.3) : several years for regions of high seismicity, and may be longer for regions of low seismicity
    - ※ US NRC(Reg. Guide 1.165 & 1.208) : at least five years prior to construction of a nuclear unit at a site

PSHA Requirement

- Background
  - ✓ Imposition of PSHA as a requirement in design earthquake determination
- Revision Direction
  - ✓ **Probability of Acceptance (Pa)**
    - Mean annual exceeding probability: 1.0E-3
  - ✓ **Safe Shutdown Earthquake (SSE) Determination**
    - Estimate the SSE by the deterministic method
    - Perform PSHA to calculate the mean annual exceeding probability of the SSE (Pe)
    - If Pe > Pa, increase the estimated SSE until Pe ≤ Pa
    - Do not decrease the SSE even if Pe < Pa

Population Center Distance Requirement

- Background
  - ✓ The NPPs shall be located some distance, app. 7.5 km, away from densely populated area called population centers
    - ✓ Required by the MEST Notice 2009-37
  - ✓ Korea is expected to face the difficulties to meet the site limit criteria related to population center
    - New NPPs as well as operating ones
    - Similar circumstance with other highly populated countries
- Revision Direction
  - ✓ Establishment of the practical alternatives, such as optimizing EPZ-related criteria and practices
    - ☑ Through analyzing regulatory principles and practices of European countries not applying the site limit to population centers

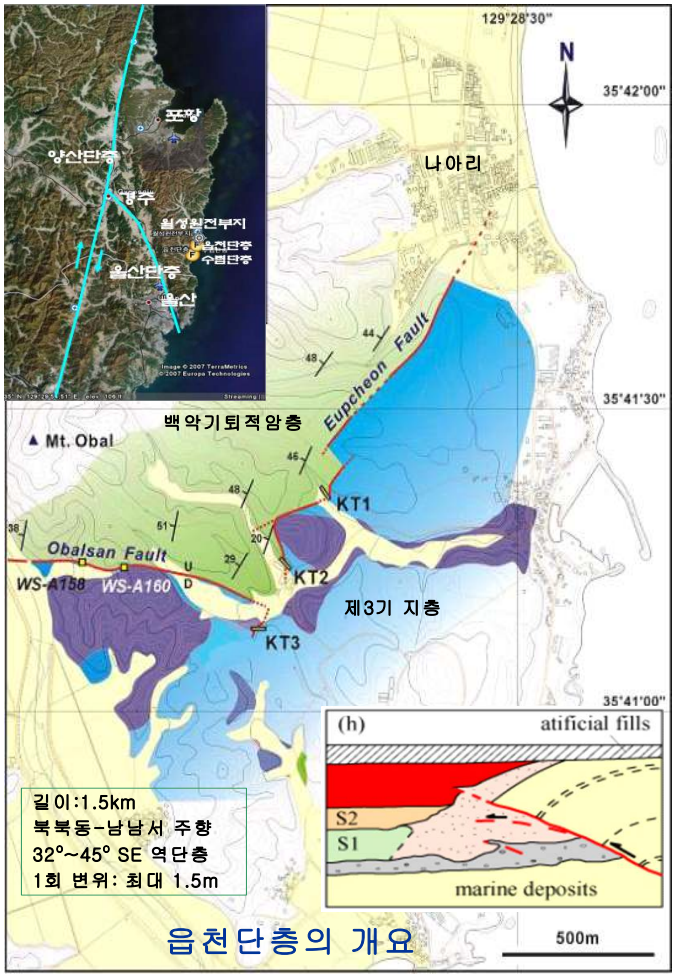
6. Recent Siting-Related Issues Experienced in Korea

- Seismic Issue at Shin-Wolsong Site
- Underwater Intake and Discharge System
- Groundwater Monitoring for Detecting the Uncontrolled Release of Liquid Radioactive Substances
- Population Distribution and Centers
- Seismic Safety Enhancement
- Requirements for Aircraft Crash
- Preliminary Assessment for the Effects of Hazard Factors Caused by Global Warming and Other Events
- National Actions Taken in Korea after Fukushima Accident

Seismic Issue at Shin-Wolsong Site

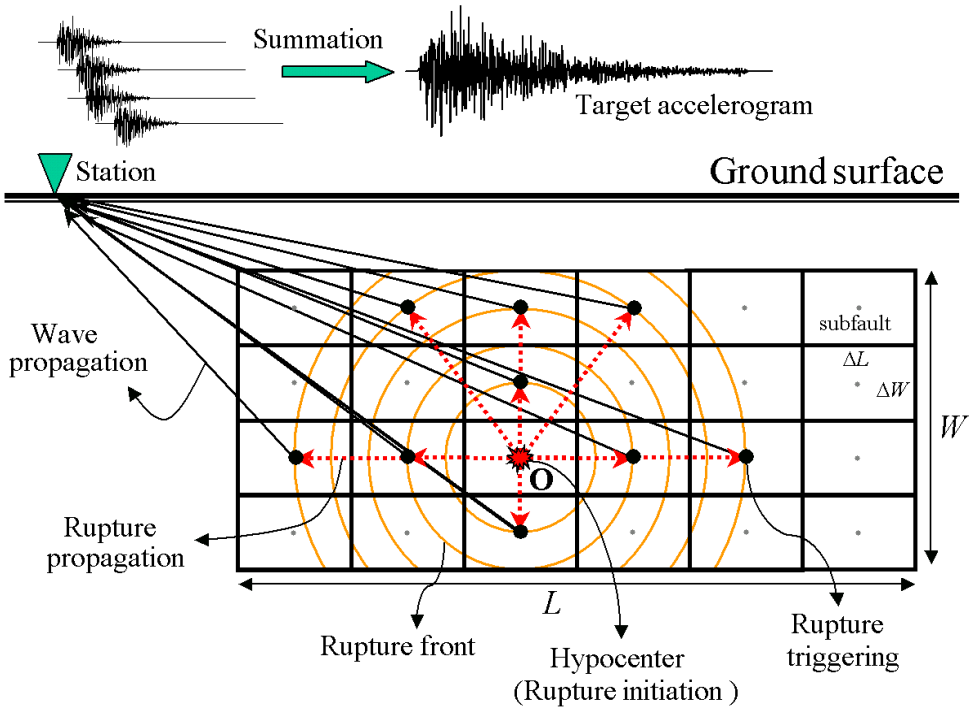
- ✓ Safety review for construction permit for Shin-Wolsong units 1 & 2
  - At the stage of site investigation for this area, a fault was identified near the site
    - Eupcheon fault: 1.5 km long, about 3 km south to the site
  - The fault was identified as a capable one based on the observation of evidences of movements
    - At least twice during 80,000~214,000 years B.P
  - A detailed analysis and investigation had been performed to check the seismic design adequacy of planned units
    - Whereas the fault is not required to be considered in the determination of the design earthquake due to its short length
  - It was confirmed that the earthquake potential of the Eupcheon fault does not affect the current seismic design

Seismic Issue at Shin-Wolsong Site



읍천단층의 개요

Eupcheon Fault



Conceptual Fault Source Model

Underwater Intake and Discharge System

- Background
  - ✓ To minimize the effect on the temperature of recirculation water for nearby operating units at the multi-units site ⇨
  - ✓ To preserve the coastline

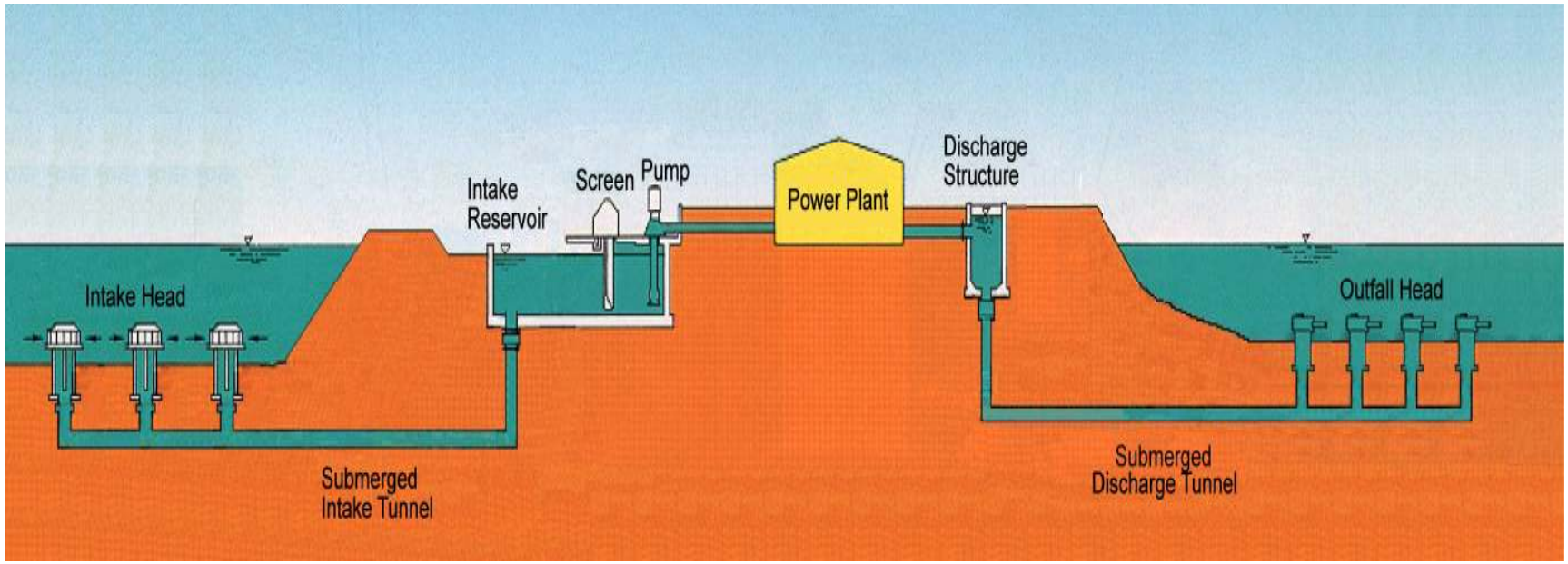
- Main Activities

	Shin-Kori 1 & 2	Shin-Wolsong 1 & 2	Shin-Kori 3 & 4
Intake	Surface water - Essential Service Water : SR - Component Cooling Water : NSR	Underwater - Essential Service Water (-5 m) : SR - Component Cooling Water(-20 m): NSR	Underwater (-20 m) - Essential Service Water : SR - Component Cooling Water : NSR
Discharge	Underwater : NSR	Underwater : NSR	Underwater : NSR

SR : Safety Related, NSR : Non- Safety Related

  - ✓ Temperature differences between surface water and underwater
    - ≒ 2.7 °C (-10 m), ≒ 6.2 °C (-20 m), in Summer

Underwater Intake and Discharge System



Seismic Category I Structure (Shin-Kori 3 & 4) ;

Submerged Intake Tunnel, Intake Reservoir, Intake Structure, etc.

Groundwater Monitoring for Detecting the Uncontrolled Release of Liquid Radioactive Substances

- Background
  - ✓ Uncontrolled releases of liquid radioactive substances at the NPP site were reported in US (Braidwood, 2005, etc.), Canada, etc.
    - No problem in the aspect of radiation exposure, but sensitive to the public
    - Leakage source : underground buried pipe, spent fuel pool, etc.
  - ✓ USNRC developed Regulatory Guide (RG) 4.21 in 2008, and revised RGs 1.21 and 4.1 in 2009
- Main Activities
  - ✓ Installation of groundwater monitoring wells on the operating units as the improvement of Periodic Safety Review, etc. in Korea
    - Kori units 1 & 2, Wolsong unit 1
  - ✓ Installation of groundwater monitoring wells on the new reactor sites such as Shin-Kori units 1 & 2, Shin-Wolsong units 1 & 2

Population Distribution and Centers

- Background
  - ✓ Regulatory safety review for the Kori unit 1 license renewal
    - A big development plan with several tens of thousand residents around the NPP site
      - ☞ Population Centers containing more than about 25,000 residents shall not be in the distance of 7.5 km from the plant
  - ✓ Necessity to define outer boundaries of the Population Centers and the closest distance to the plant
- Main Activities
  - ✓ Verification of the distribution of the Population Centers by establishing a GIS-based population distribution map
    - Population data, geographical map, land use type, development projects of the local government, etc.
  - ✓ It was confirmed that there were no Population Centers within 7.5 km from the Kori unit 1

* GIS : Geographic Information System

Seismic Safety Enhancement (1/3)

- Background
  - ✓ Niigataken Chuetsu-Oki (NCO) EQ, Japan (2007.7.16)
  - ✓ The MEST ordered KHNP to take measures for seismic safety enhancement of NPPs against strong ground motions just after the NCO EQ.
- Main Activities
  - ✓ Investigation of lessons learned from the impact on and countermeasures taken at the Kashiwazaki-Kariwa (K-K) NPP
  - ✓ Survey and analysis of NPPs, in Japan and the US, that have experienced strong earthquakes exceeding design basis
  - ✓ Assessment of effects of earthquakes exceeding the design basis on domestic NPPs
  - ✓ Derivation of seismic safety enhancement measures against strong earthquakes

Seismic Safety Enhancement (2/3)

➢ Major Derived Measures

- ✓ Introduction of automatic scram system in case of earthquakes exceeding threshold setting values (~ 2012)
- ✓ Upgrade of plant level HCLPF values based on seismic margin assessment results (~ 2014)
- ✓ Upgrade of seismic capacity of non-safety class items
  - Anchorage systems of transformers; temporary storage facilities of low-level radioactive waste
- ✓ Intensification of training for operator actions in case of earthquakes, etc.

* HCLPF : High Confidence of Low Probability of Failure

Seismic Safety Enhancement (3/3)

Reinforcement of the Anchorages of Main Transformers

Requirements for Aircraft Crash

- Korean utility has to evaluate the possibility of accidental aircraft crashes at the design stage
  - Article 13 (Design Bases for External Events) of “Regulation on Technical Standards for Nuclear Reactor Facilities, Etc.”
- NPPs in operation and under construction in Korea are permitted not to consider an aircraft crash for design
  - Estimated probability of an accidental aircraft crash is very low, which is lower than 1.0E-07/RY
  - The screening criteria are as follows :
    - Within 3.2 km (2 mi) : No airway, no approach route, no staying route
    - Within 8 km (5 mi) : No airport, no airway for military training
    - Within 16 km (10 mi) : No airport with annual flight frequency exceeding 193 X D^2
    - Beyond 16 km : No airport with annual flight frequency exceeding 386 X D^2

      * D: distance (km) from the airport to the plant
- MEST/KINS are preparing for the rulemaking, considering the intentional aircraft crash

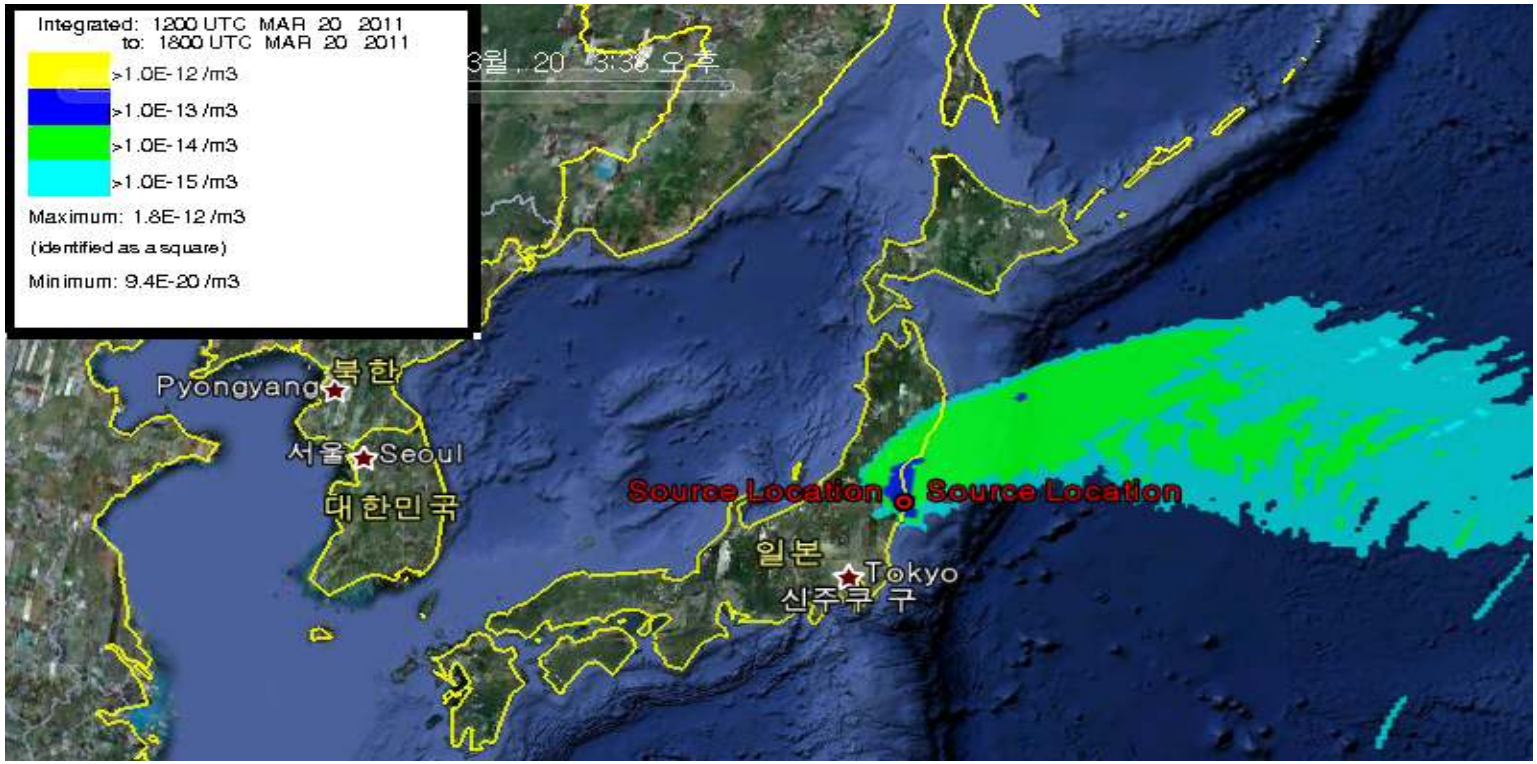
Preliminary Assessment for the Effects of Hazard Factors Caused by Global Warming and Other Events

- Background
  - ✓ Effect of global climate change on the safety of NPPs in Korea
    - Rise of seawater temperature, raised seawater level, local heavy rainfall, intensified typhoon etc. on & around Korean peninsula
  - ✓ Effect of other site specific events on the safety of NPPs
    - Forest fire, oil spill accident at sea, inflow of marine organism into the intake such as very small shrimp, etc.
- Main Activities
  - ✓ Preliminary evaluation of the effects of the hazard factors on the safety of NPPs
  - ✓ It was confirmed that there are no significant factors related to the global climate change and site specific events, which can affect the safety of operating NPPs in Korea

Preliminary Assessment for the Effects of Hazard Factors Caused by Global Warming and Other Events

National Actions Taken in Korea after Fukushima Accident (1/8)

- **MEST/KINS operates emergency situation center since the Fukushima accident, monitoring and assessing the radiological consequence.**
- **MEST/KINS announces the measured radioactive concentration of I and Cs across the country on a daily basis.**
- **Air Current Analysis and Anticipation (21 March)**



National Actions Taken in Korea after Fukushima Accident (2/8)

Special Inspection (23 March ~ 30 April)

- To evaluate the safety of facilities against the earthquake and the Tsunami
- Facilities: All operating NPPs (21 units)
- Inspection Team: 73 experts
  - KINS 37, other expert from private sector 36
- Fields of Inspection (6 areas & 27 items)
  - Structural Integrity (Seismic Resistance)
  - Integrity of Electrical Power and Cooling Systems
  - Facilities and Systems against Severe Accidents
  - Effectiveness of SAMG
  - Emergency preparedness and medical systems
  - Effectiveness of Radiation Emergency Plan

National Actions Taken in Korea after Fukushima Accident (3/8)

Inspection Findings and Actions

1. Seismic Resistance

- Findings:
  - Sufficient safety margin exists for all units against maximum potential earthquake
  - DBEs for OPR1000: 0.2g, for APR-1400: 0.3g

- Actions:
  - Improvement of reactor shutdown system in order for the reactor to get automatically shutdown in case an earthquake whose magnitude greater than 0.18g occurs. (for all units, by 2012)
  - Reevaluation of seismic capability of safe shutdown system such as shutdown cooling system, residual hear removal (RHRS), etc. and strengthening system to a level of new reactor's design earthquake (0.3g). (for all units, by 2014)
  - A comprehensive reassessment of maximum potential earthquake for all sites (by 2013)

National Actions Taken in Korea after Fukushima Accident (4/8)

Inspection Findings and Actions

2. Tsunami Resistance

❑ Findings:

- ❖ Sufficient safety margin exists for all units against maximum potential sea levels (narrowest margin is 0.3m for Kori Units 1&2)
- ❖ Maximum potential sea levels: 5.7m~8.4m
- ❖ Units are located on 10m above sea level for Yonggwang and Uljin, 12m for Wolseong, 7.2m for Kori Units 1&2, 9.5m for Kori Units 3&4

❑ Actions:

- ❖ To extend seawall of Kori site whose safety margin to tsunami is relatively low to the level of other sites (10m). (for Kori site, by 2012)
- ❖ To install water-proof door and water-proof drain pump in relavant facilities to prevent flooding of emergency power systems and major safety system (for all units, by 2014)
- ❖ A study and examination on maximum potential tsunami near Korean peninsula (by 2012)

National Actions Taken in Korea after Fukushima Accident (5/8)

Inspection Findings and Actions

3. Reliability of Power Supply and Cooling System

❑ Findings:

- ❖ Equipped with redundant power supply system
- ❖ To cope with loss of offsite-power, 2 EDGs per unit + Alternative AC
- ❖ Multiple sources of water for emergency cooling of spent fuel pit

❑ Actions:

- ❖ To cope with a flooding, a car equipped with mobile emergency generator and battery will be deployed in a safe place (for each site, by 2014)
- ❖ To cope with the loss of cooling for spent fuel pool, a countermeasure includes supplying makeup water using fire engine (for all units, by 2011)
- ❖ Improvement of design standard of AAC considering incidents in multiple reactors on the same site. (for all units, by 2014)
  - e.g., modification of capacity of alternative emergency diesel generator, diversification of cooling method (air cooling & water cooling) for EDGs and AACs

National Actions Taken in Korea after Fukushima Accident (6/8)

Inspection Findings and Actions

4. Response to Severe Accidents

- Findings:
  - Severe accident management guidelines had been prepared for all units
  - Appropriate education and training for severe accident
  - Various kinds of igniters or recombiners for hydrogen control in containment (nothing in Wolseong Unit 1)

- Actions:
  - To install passive hydrogen removal equipments to prevent hydrogen gas explosion (for all units, by 2013)
  - To be equipped with venting/depressurization device to cope with pressure buildup in containment during severe accident (for all units, by 2015)
  - To install coolant injection lines from outside the primary and secondary system for emergency cooling (for all units, by 2015)

National Actions Taken in Korea after Fukushima Accident (7/8)

Inspection Findings and Actions

5. Emergency preparedness and medical treatment

❑ Findings:

- ❖ Appropriate emergency measures, including organization, facilities, protective action guidelines
- ❖ Regular educations and drills
- ❖ Designated medical treatment centers for radiation emergency

❑ Actions:

- ❖ To secure additional radiation protection medicine (potassium iodide) and gas mask for residents near sites (by 2012)
  - ▪ Prepared for population within 10km radius→ within 16km radius
- ❖ To modify the 'radiological emergency plan' for an emergency response organization to be set up considering multiple emergency, and to have declaration criteria considering magnitude of tsunami (by 2011)

National Actions Taken in Korea after Fukushima Accident (8/8)

- In addition to the actions taken already,
- Korea will actively participate in the international efforts to feedback the lessons learned from Fukushima NPPs Accident, and take a proper action.

Thank you very much

KINS