Korean Case Study on Nuclear Power Technology

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Contents

1. Nuclear surprises in 2009

- **May 25: NK detonated its second NW**
  - **Test site Punggye, yield 2-6 kiloton Pu type**
  - **UNSC Resolution 1874, stiff sanctions**

- **Dec. 27: SK consortium won UAE NPP project**
  - **"Surprise Choice"**
  - **4X1400 MWe APR, first in GCC**

- **Dec. 4: KAERI won Jordan RR supply contract**
- **June, 2010: KEPCO sole bidder for Turkey Sinop NPP**

Questions

- ***How could they do it?***
- ***How credible is it?***
- ***What are the lessons?***

UAE Nuclear Power contract

- **NPP turnkey package contract**

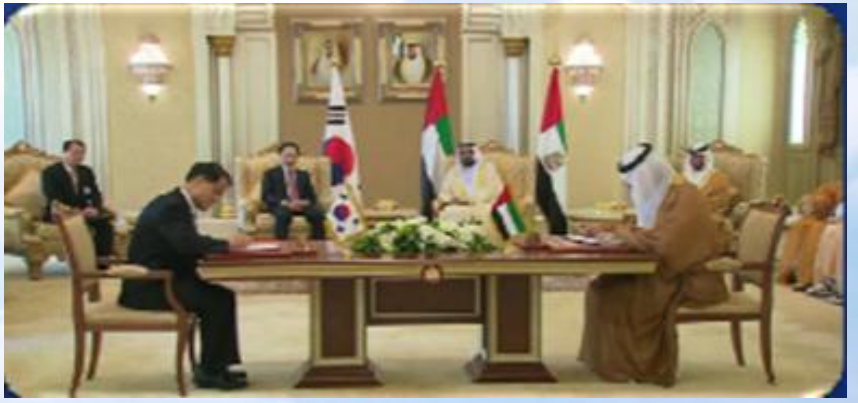
APR 1400 4 Reactors

Supply of Nuclear Fuel
(for next 3 yrs)

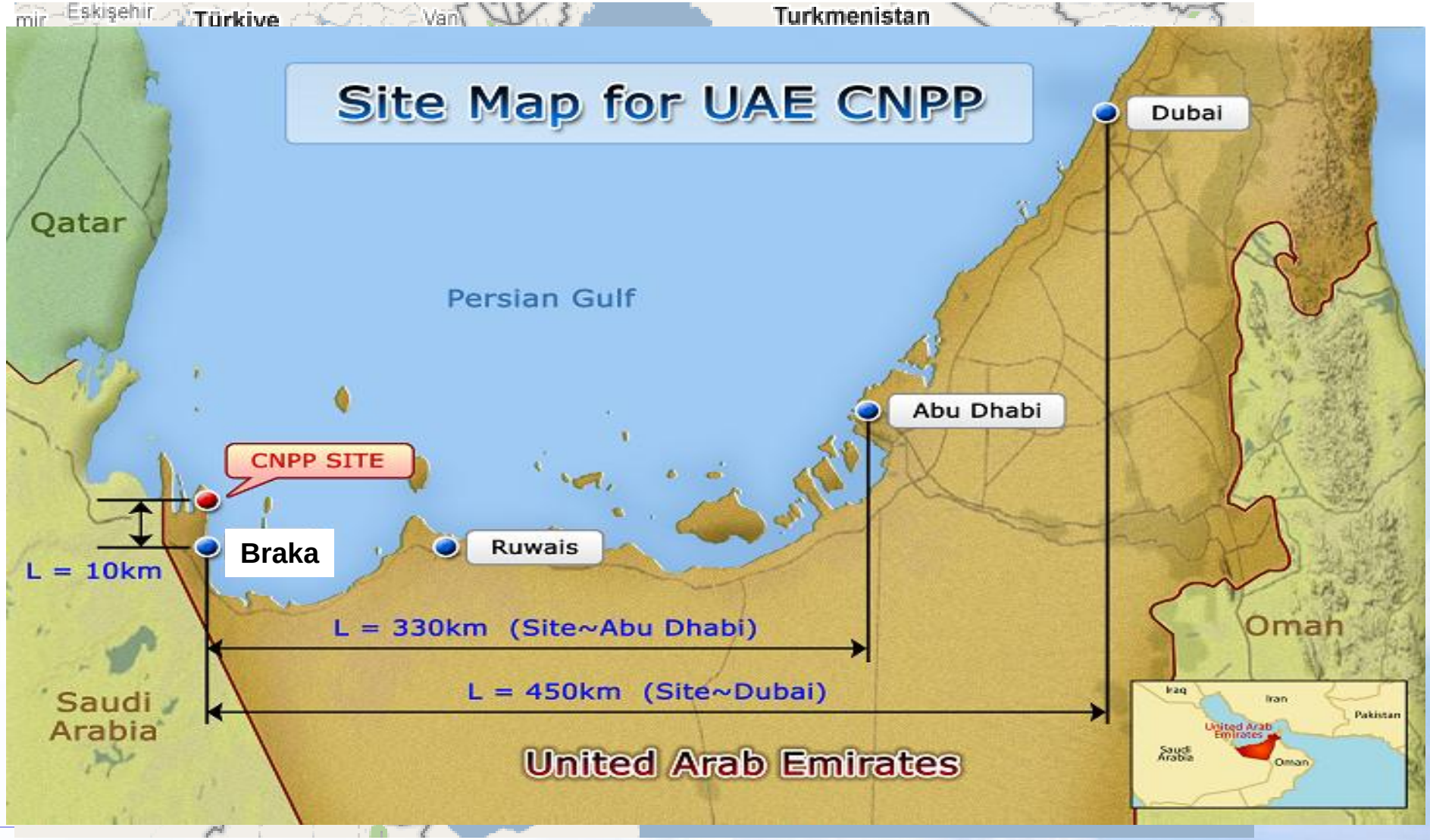
Support of Operating
and Maintenance

Education & Training

- **Contract worth**
  - **$ 20 billion +**
- **Completion schedule**
  - **2017 - 2020**



UAE NPP Braka Site



Summary of UAE Project

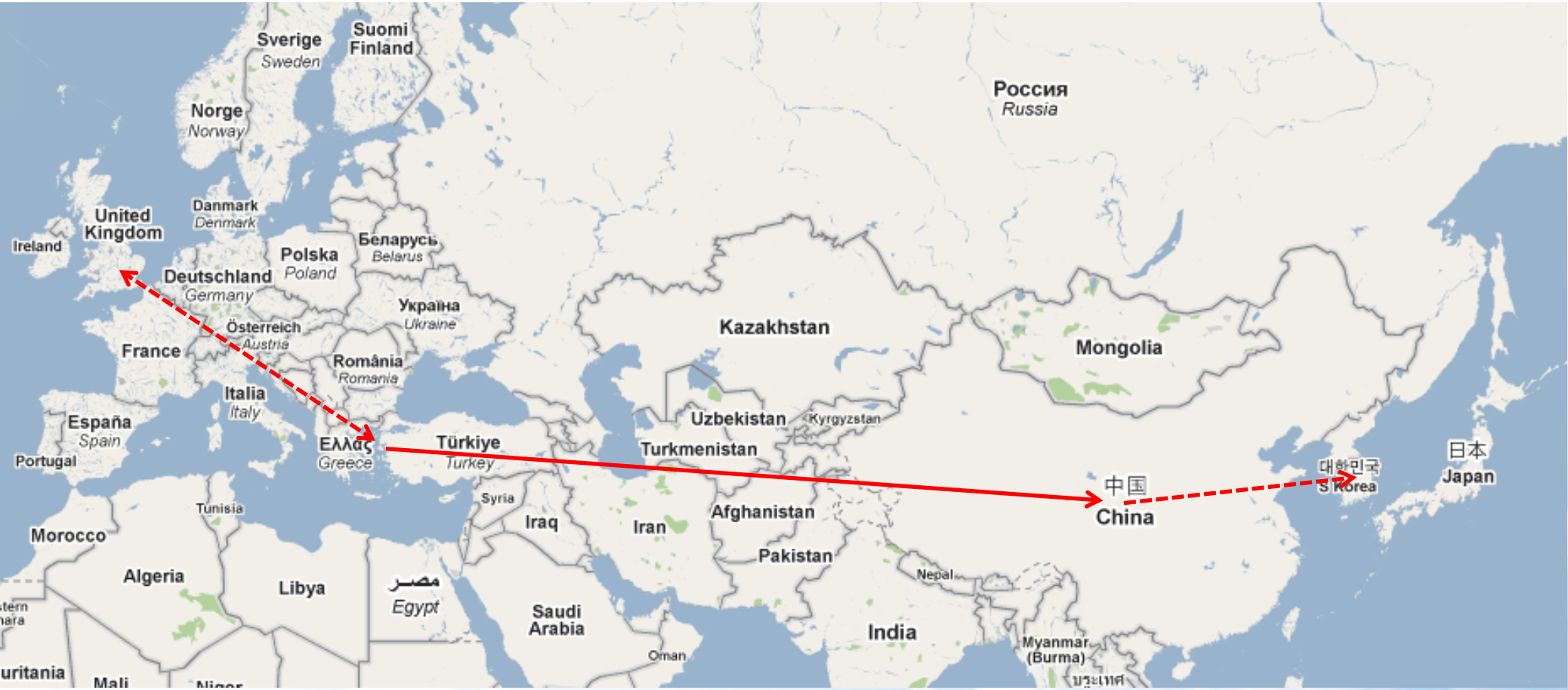
- **International tender: Areva/H-GE/KEPCO**
  - **Single largest NPP project ~ $3,300/kW**
- **UAE selection comment**
  - ***"Proven safety and economy"***
- **UAE/ROK common nonproliferation doctrine**
  - **No reprocessing, no enrichment**
- **Emergence of a new NPP supply chain from Asia**

Jordan Research Reactor

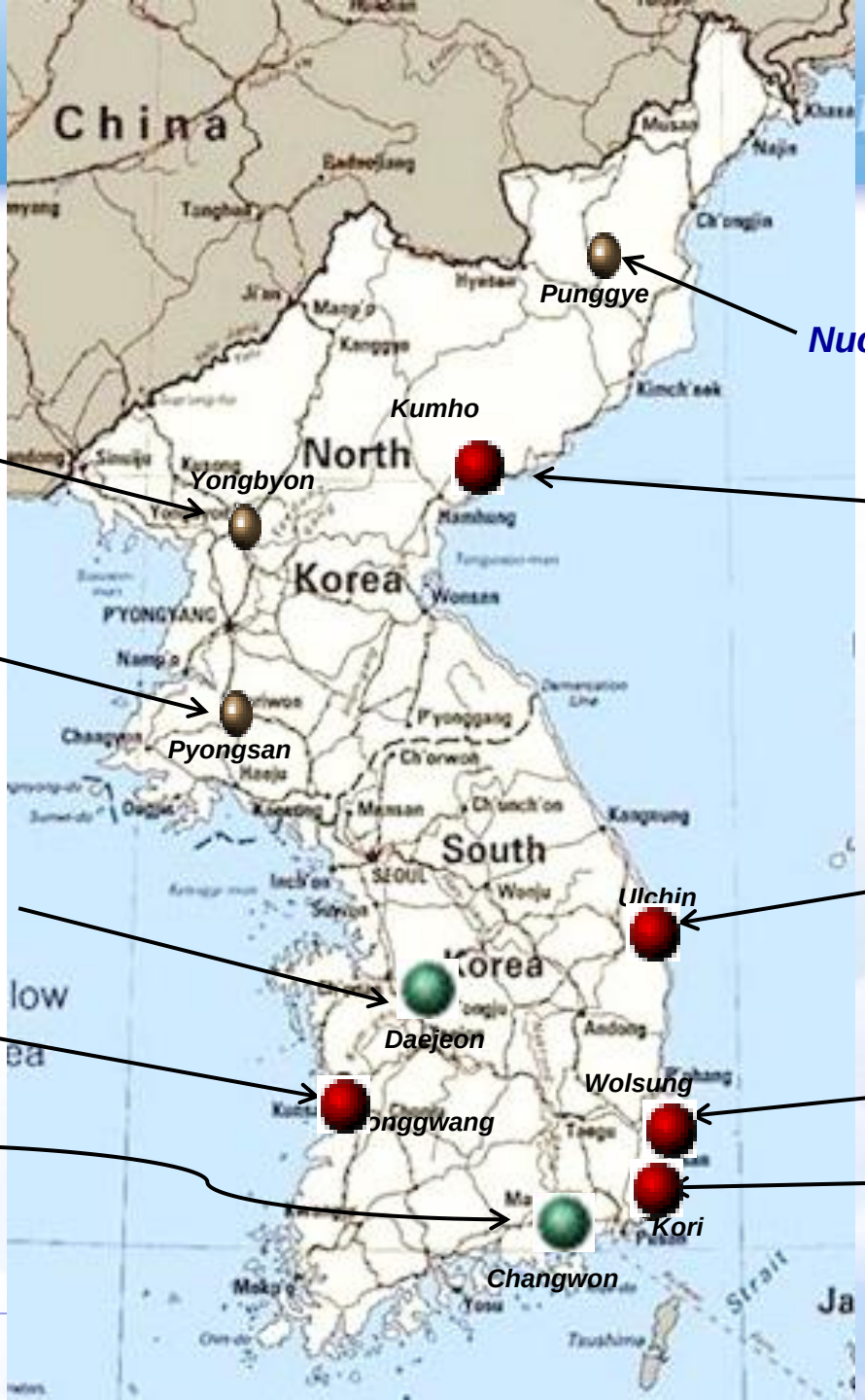
❑ Project Summary

- Start Date: March 30, 2010
  Completion: Feb. 2014
  Capacity: 5MW
- Ref. Plant: HANARO, 30MW

2. Bit of geography/history



Nuclear map of KOREA



Nuclear test site

Nuclear R&D center

KEDO LWR site

Uranium mine

Daedeok Innopolis
Nuclear R&D, safety,f uel

Ulchin NPP (U)

Yonggwang NPP (Y)

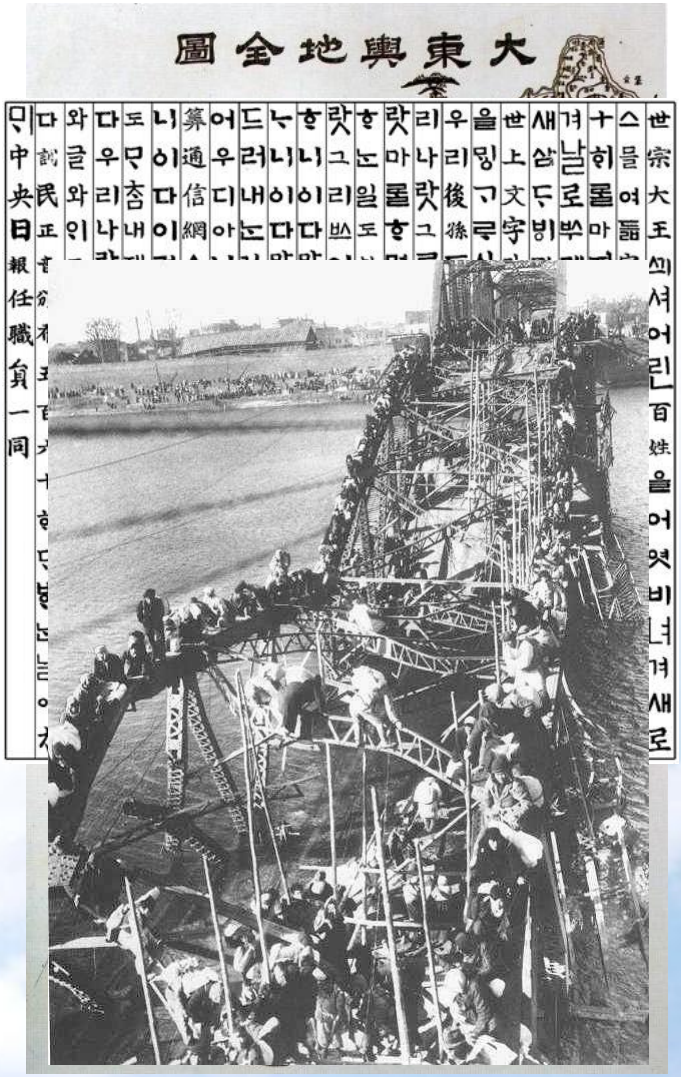
Wolsong NPP (W)
Radwaste repository

Nuclear heavy industry

Kori NPP (K)

2. Bit of history

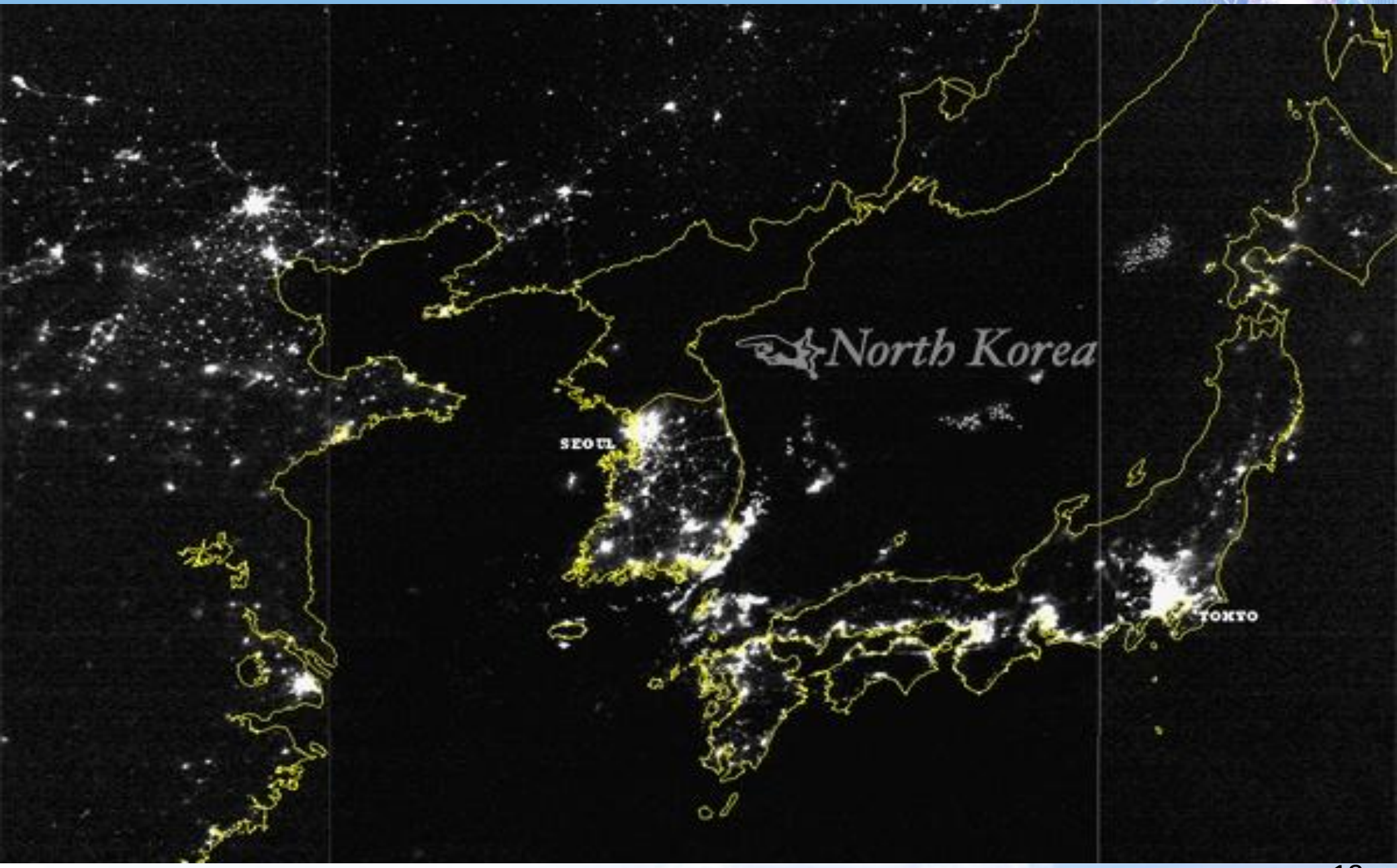
- Unified peninsula until 1945
- Same race, language, history
  - Korean alphabet "Hangul" 1446
- Communist DPRK/democracy ROK
- Bitter Korean War (1950-1953…)
- Nuclear dichotomy since 1970's
  - North: NW for blackmail, isolation
  - South: NPPs for economic miracle



Land of extreme contrasts

	N	S	N/S %
Pop (mil)	23	49	48
PCI ($)	1,060	19,000	6
Elec(bkWh)	255	4,200	6

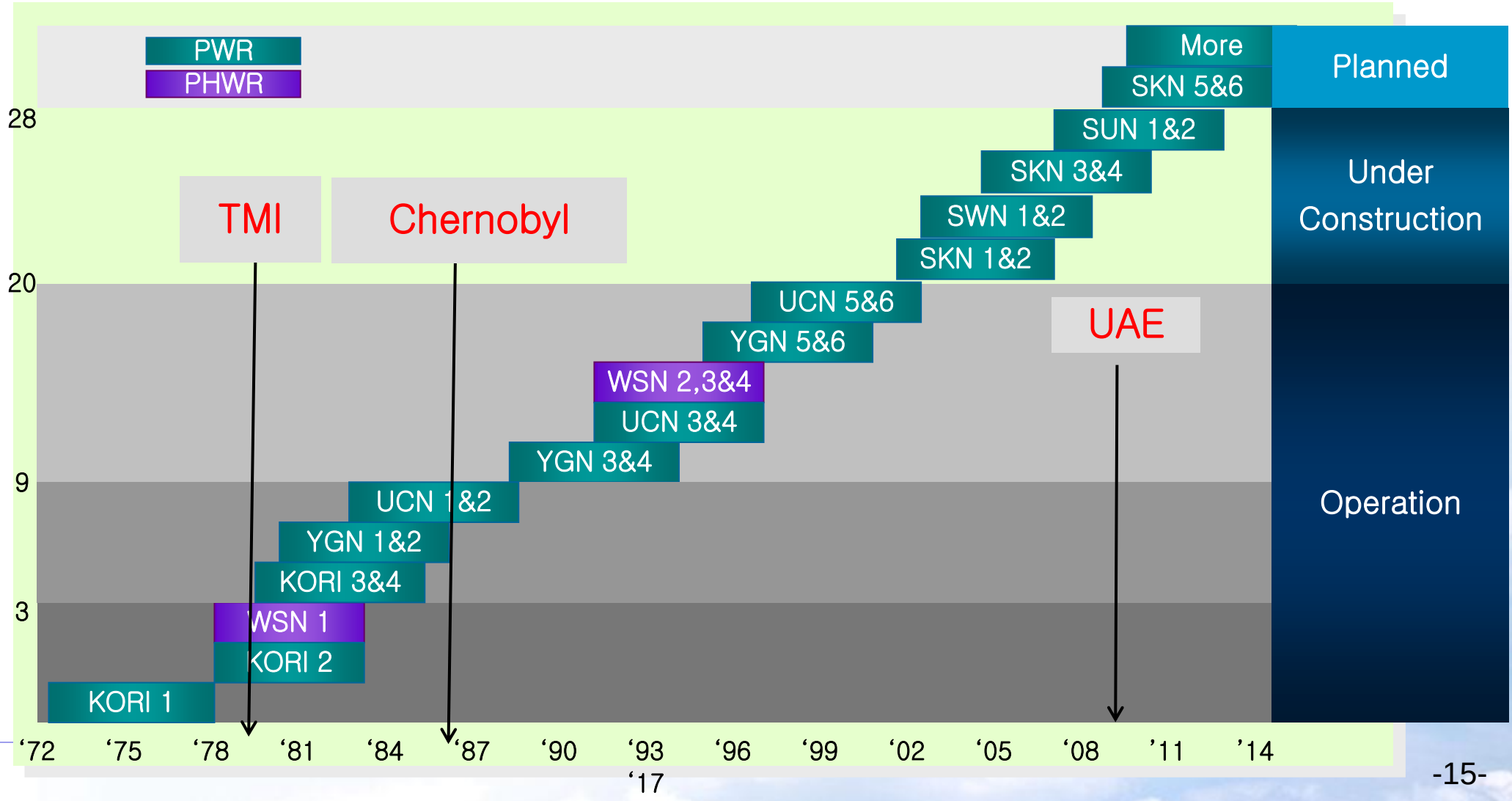
"and the gap is widening"


North Korea
SEOUL
TOKYO

3. Korean nuclear overview

- 1959: Atomic Energy law, KAERI founded
- 1968: Official first NPP construction plan approved
- 1978: Kori-1 commercial operation
- 1987: Yonggwang-3/4 construction with Technology Transfer
- 1995: Y3/4, NPP technical self-reliance 95% achieved
- 1998: First KSNP U3 commercial operation
- 2009: First NPP turnkey export to UAE

Nuclear Power Plants chronology in Korea



Nuclear power generation 2009-10

Country	*GWe*	TWh	Units	%Elec
USA	*101*	797	104	20
France	*63*	392	58	75
Japan	*47*	263	54	29
Russia	*23*	153	32	18
S Korea	*18*	141	20	35
Germany	*20*	128	17	26
Canada	*13*	85	18	15
Ukraine	*13*	78	15	49
China	*9*	66	11	2
Spain	*7*	50	8	18
Sweden	*9*	50	10	35
WORLD	*374*	2 558	438	14

4. Koreanization of nuclear power technology

4.1 Nuclear policies from heads of State

4.2 National lab's participation

4.3 Utility's project management, operations

4.4 Nuclear industries' commercial competitiveness

plus good luck, and timing

4.1 Nuclear policies from heads of State

- **50's: Rhee Syngman**
  - **"Atomic machine", education/manpower**
- **70's: Park Chung-hee**
  - **Choice between peaceful nuclear power over military use**
- **80's: Chun Doo-hwan**
  - **Localization of NPP technology, KAERI's role**
- **2009: Lee Myung-Bak**
  - **Summit diplomacy, super salesman**

Leadership of Han Pil-soon

(KAERI president for 1982 – 1991)

- "CAN DO" spirit, technical self-reliance
- Transparency from commercial projects

- Step-by-step demo of confidence
  - CANDU fuel, PWR fuel, NSSS system design

- Hitch-hike strategy on proven technology
  - Know-how's from technology transfer

- *Joint Design* approach for developing country
  - Shortage of time/money/exp. manpower

NPP standardization policy (1981-85)

- **Reactor type: 1,000 MWe PWR + ADFs**
- **Technology self-reliance entity/area**
  - **KEPCO: overall project management (KHNP)**
  - **KOPEC: architect engineering**
  - **KHIC: NSSS, T/G supply (Doosan)**
  - **KAERI: NSSS system, initial core design**
  - **KNFC: nuclear fuel fabrication (KNF)**

Electric Power Group Cooperation Council

4.2 National lab's (KAERI) participation

- Breakdown of reprocessing venture (1975)
- Name change: "Atomic" to "Advanced"(1980)
- CANDU/PWR fuel localization (1983)
- KAERI in the commercial NPP projects (1985)
  - NSSS system, initial core design
  - Int'l tender among W, C-E, Fram, AECL
  - Technology buyer's market after Chernobyl
- Y3 /4 construction with Technology Transfer

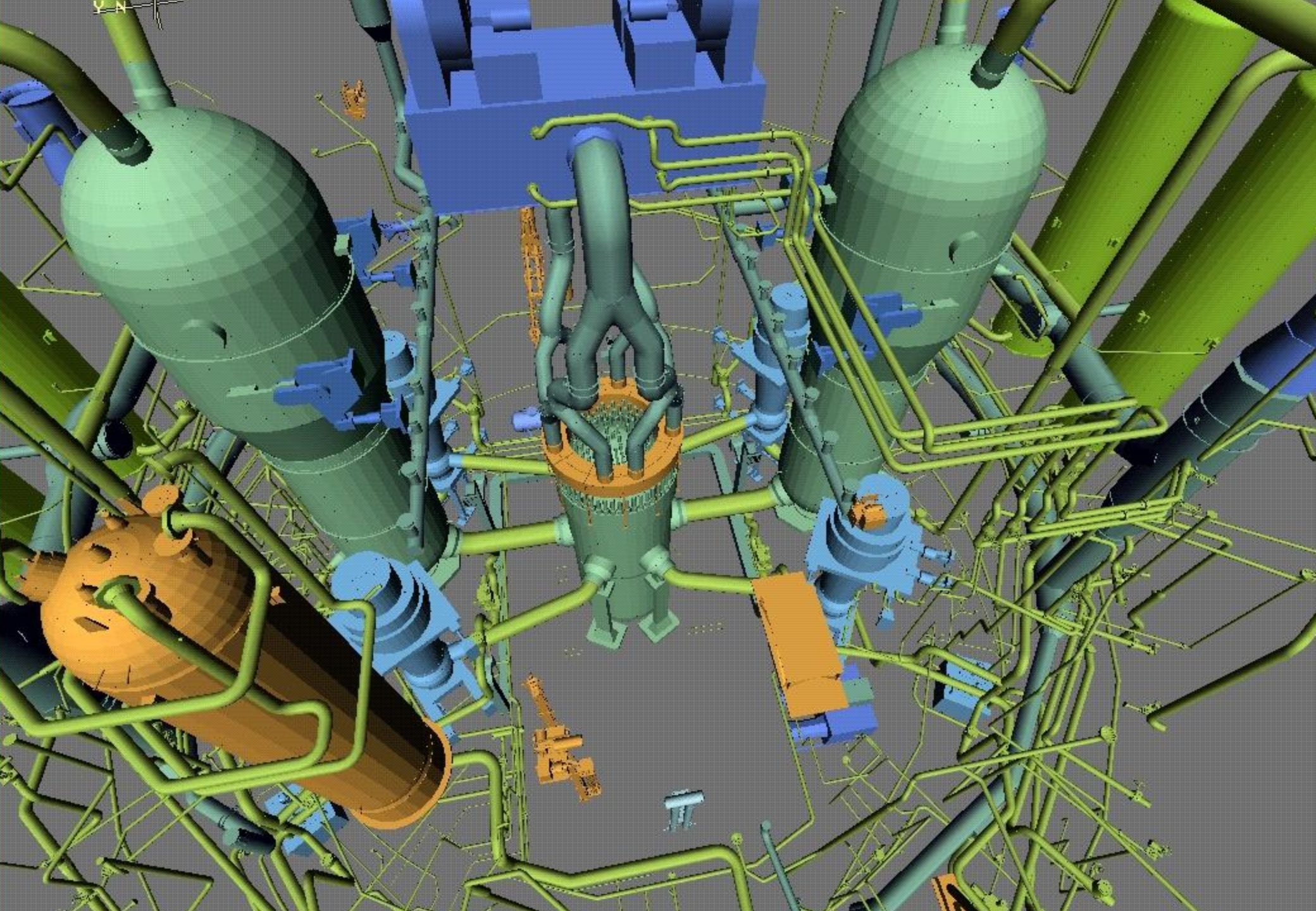
NSSS system designer's role

- Determines NPP type, power level, safety
  - Designs RCS + aux sys + safety sys + MCR
  - Top-tier know-how, know-why
- Commissioning test , performance warranty
- Reactor control and protection architecture
- Central to regulatory licensing
- NSSS vendors' reactor models
  - W: *AP1000*, Areva: *EPR*, KEPCO: *APR1400*
  - GE: *ABWR*, AECL: *EC6*, AEP: *VVER1000*, H/T/M

NSSS system design comparison (1985)

- **Westinghouse (Framatom)**
  - **RCS 2/3/4 loops, submarine technology**
  - **Largest no. built, tech transfer licensees**
  - **AP-1000, EPR development**

- **Combustion Engineering (C-E, now part of W)**
  - **RCS all 2-loop, boiler maker technology**
  - **Simpler, robust design**
  - **Only 1300 MWe System-80s built in US**
  - **No technology transfer licensing experience**



Technology Transfer thru Joint Design (1987)

- **Unique concept to overcome shortages**
  - **Experienced manpower**
  - **Save time and budget costs**
  - **Performance guarantee/warranties**

- **US/Korean counterparts**
  - **Reactor systems/core design: CE/KAERI**
  - **Plant engineering: S&L/KOPEC**
  - **Component design/manufacturing: CE/GE/KHIC**
  - **Fuel fabrication: CE/KNFC**

Technology Transfer thru Joint Design

- Transfer of design tools (1987)
  - - Computer codes, documents, patent rights
- Design center moved, US to Korea(1989)
  - - Joint design team from Windsor to Daedeok
- Transition of performance warranty
  - - Y3/4 under US warranty, U3/4 Korean
- Additional training, R&D participation
- Technical self-reliance 95% by 1995
  - - Birth of Korean reactor model OPR1000, APR1400

First KAERI Joint Design team sent to Windsor (1986)

OPR 1000 & APR 1400

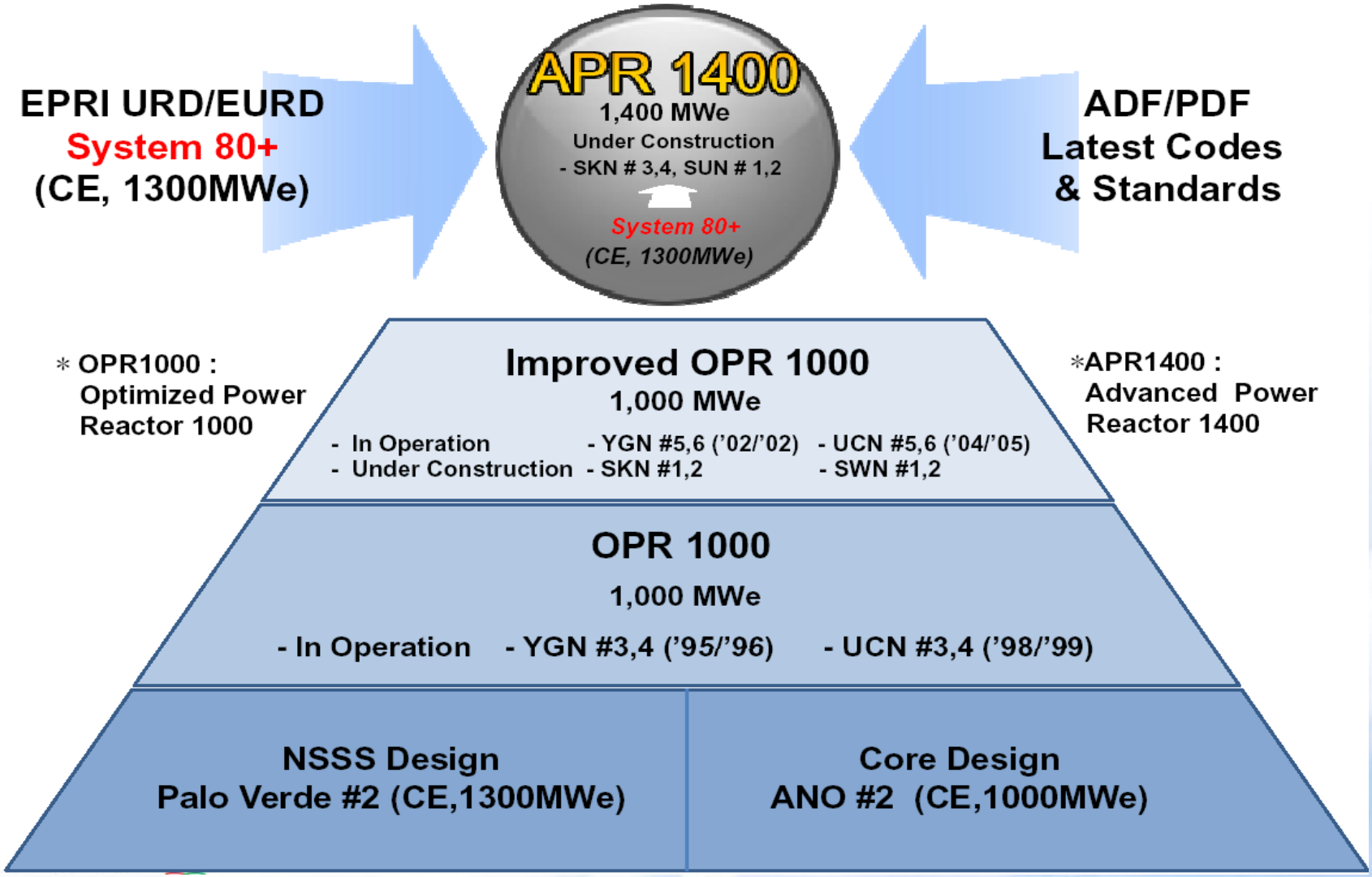
OPR1000

APR1400

Parameters	OPR1000	APR1400
Power capacity (MWe)	1000	1400
Design life time (yr)	40	60
Seismic design criteria	0.2g	0.3g
Core damage frequency	6.8×10^{-6} /RY	2.4×10^{-6} /RY
Emergency core cooling	2 Train	4 Train
Main control type	Analog + Digital	Digital

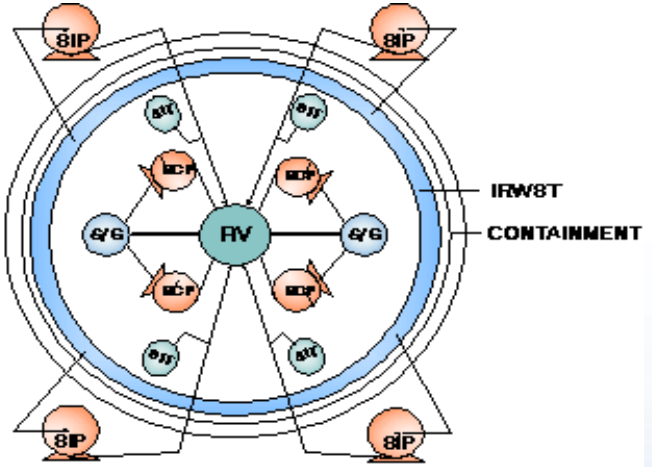
- OPR1000: Optimized Power Reactor 1000MW
- APR1400: Advanced Power Reactor 1400MW

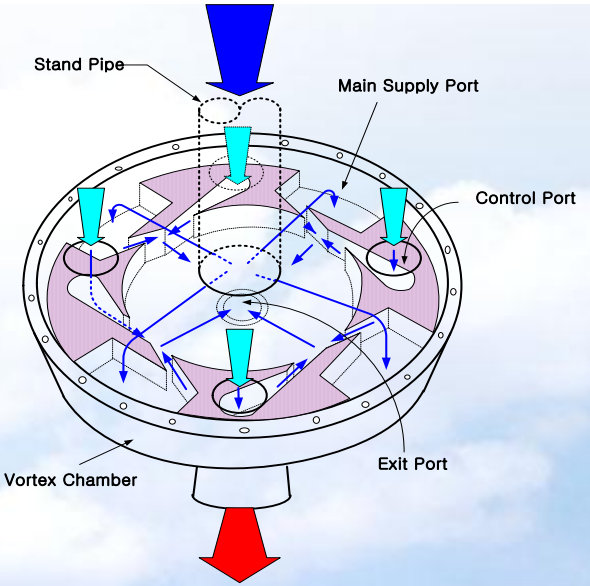
Technical Bases – Evolutionary Design



Safety System – Safety Injection System

- 4 independent trains
  - 1 SIP/train
  - 1 SIT/train
- Direct Vessel Injection (DVI)
  - No injected water spillage in LOCA
- In-containment Refueling Water Tank (IRWST)
  - No switchover for long-term cooling during LOCA
- Fluidic Device in Safety Injection Tank
  - Play the role of Low Pressure SIP





Unfinished self-reliance (5%)

- Third party owned restricted codes
  - Replacement codes developed at KAERI
    ATLAS verification test
  - Korean NPP original know-why's
- Reactor coolant pump design/manufacturing
- Main Control Room MMIS

"Westinghouse scope in UAE contract"

4.3 Utility's project management/operation

In Operation 20 units (17,716MW)

Under Construction 8 units (6,800MW)

Radioactive Waste Disposal Facility (Under construction)

Younggwang 1, 2, 3, 4, 5 & 6

Ulchin 1, 2, 3, 4, 5 & 6
Shin-Ulchin 1&2 (Under construction)

Wolsong 1, 2, 3 & 4
Shin-Wolsong 1 & 2 (Under Construction)

Kori 1, 2, 3 & 4
Shin-Kori 1- 4 (UnderConstruction)

Status of nuclear power construction

Shin Kori 1&2

Shin Wolsong 1&2

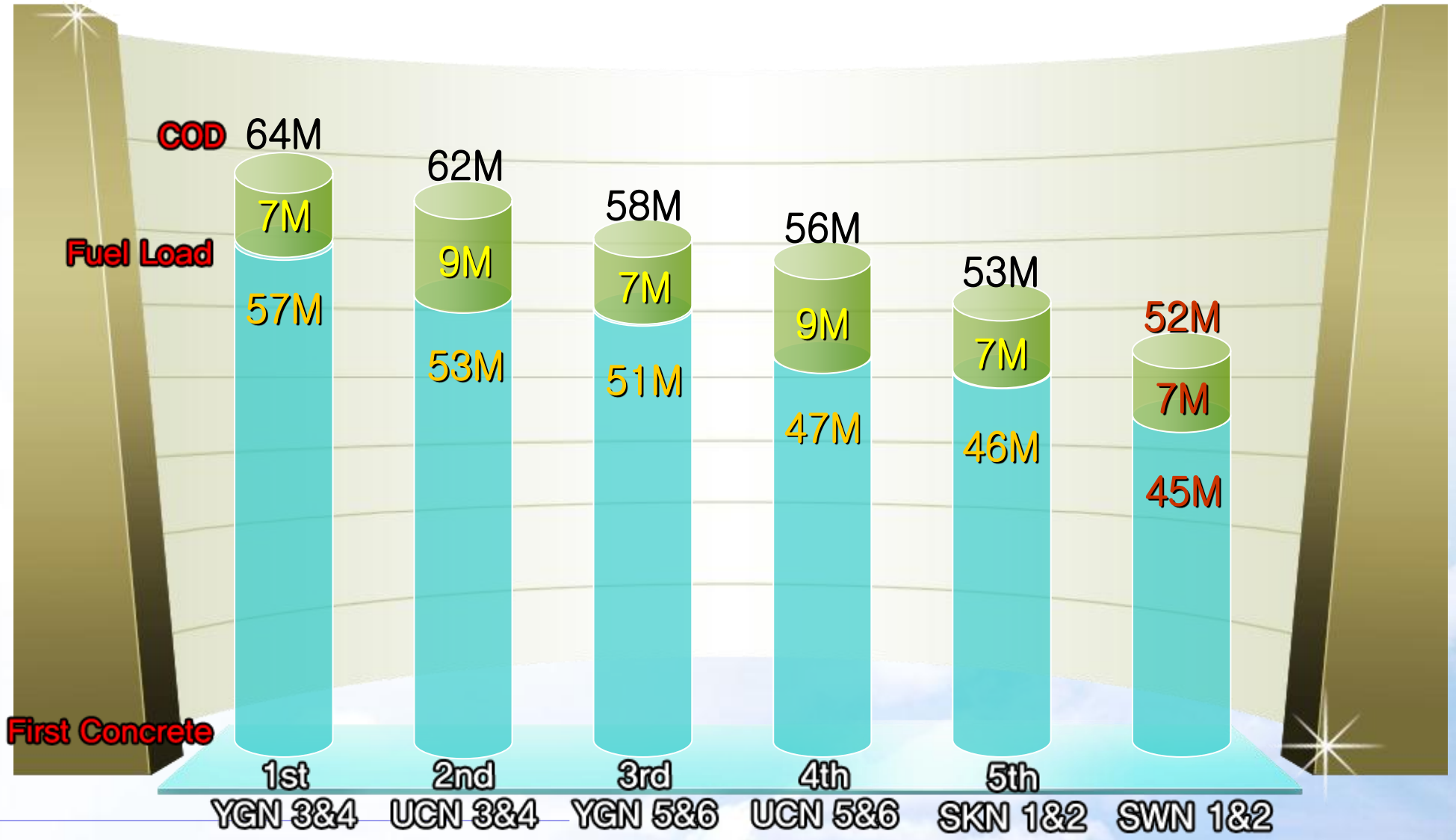
Shin Kori 3&4

Shin Ulchin 1&2

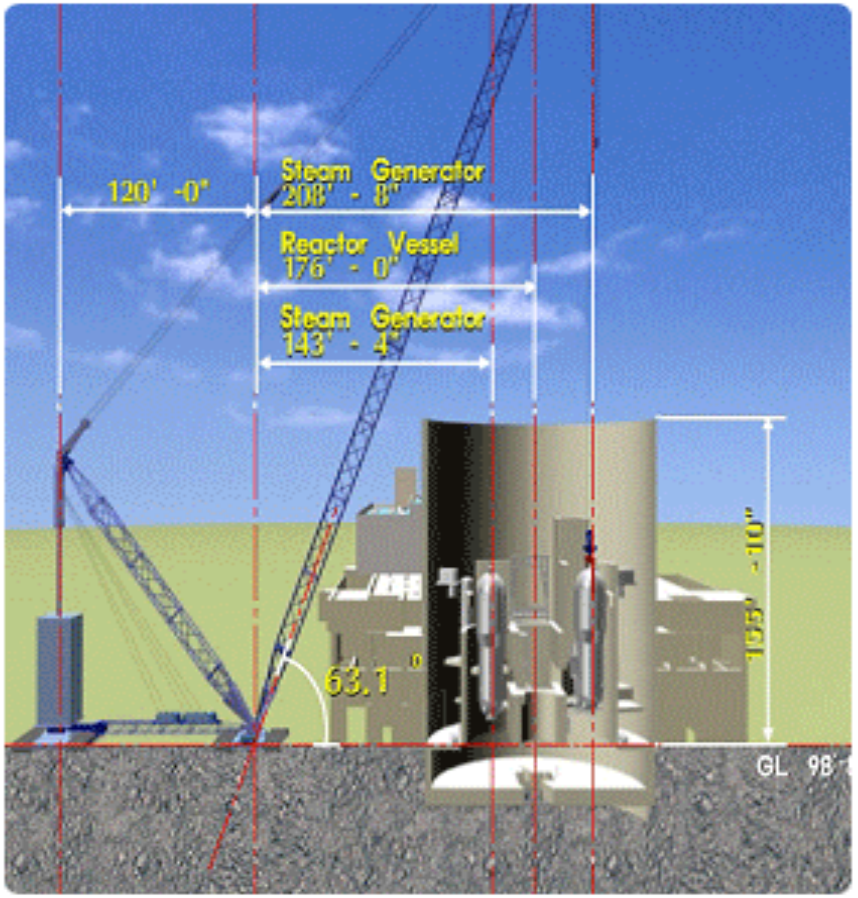
NPP construction management

- Integrated management from K1
- Project Management 3 principles
  - On time: construction period
  - In budget: initial capital cost
  - In quality: meeting ASME/IEEE codes
- KEPCO lead, EPGCC teamwork
- Lessons learned from repeat projects

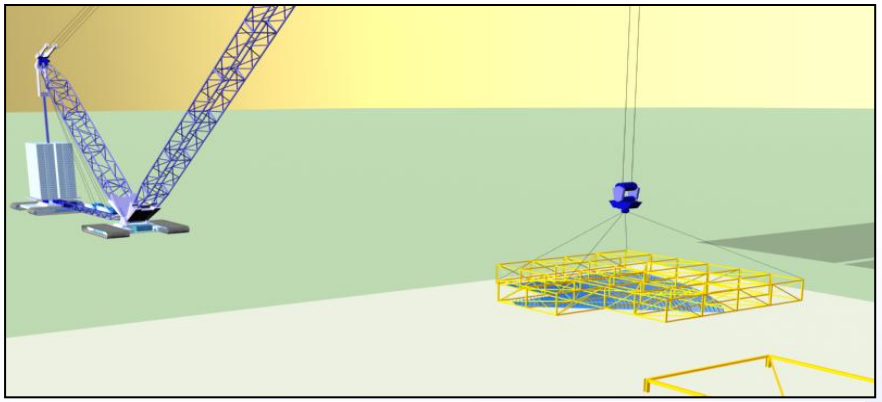
Construction Period

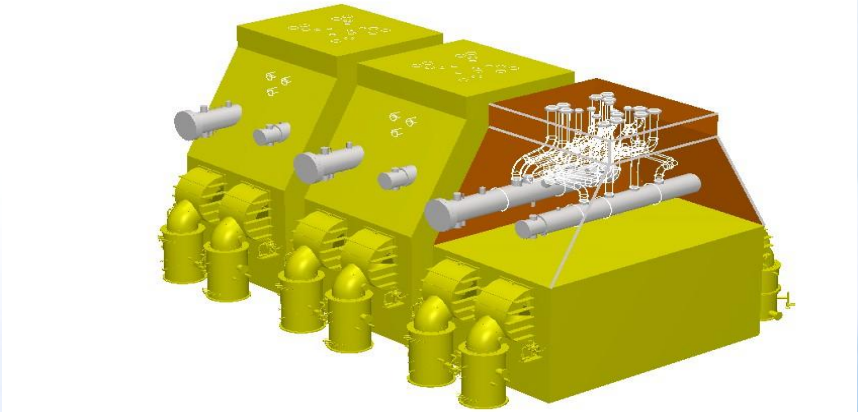


Enhancement of Construction Method



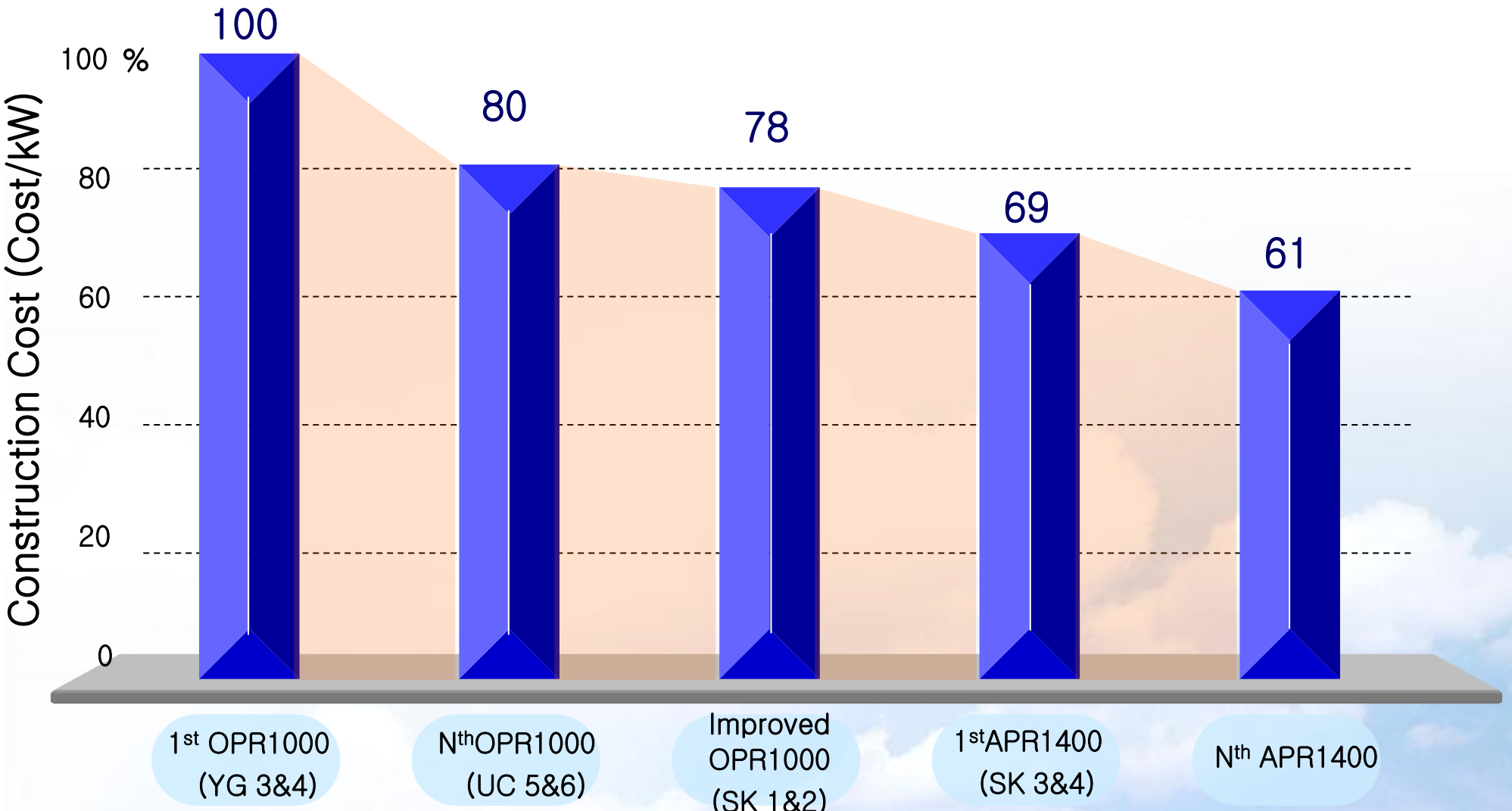
Open- Top Method





Modularization

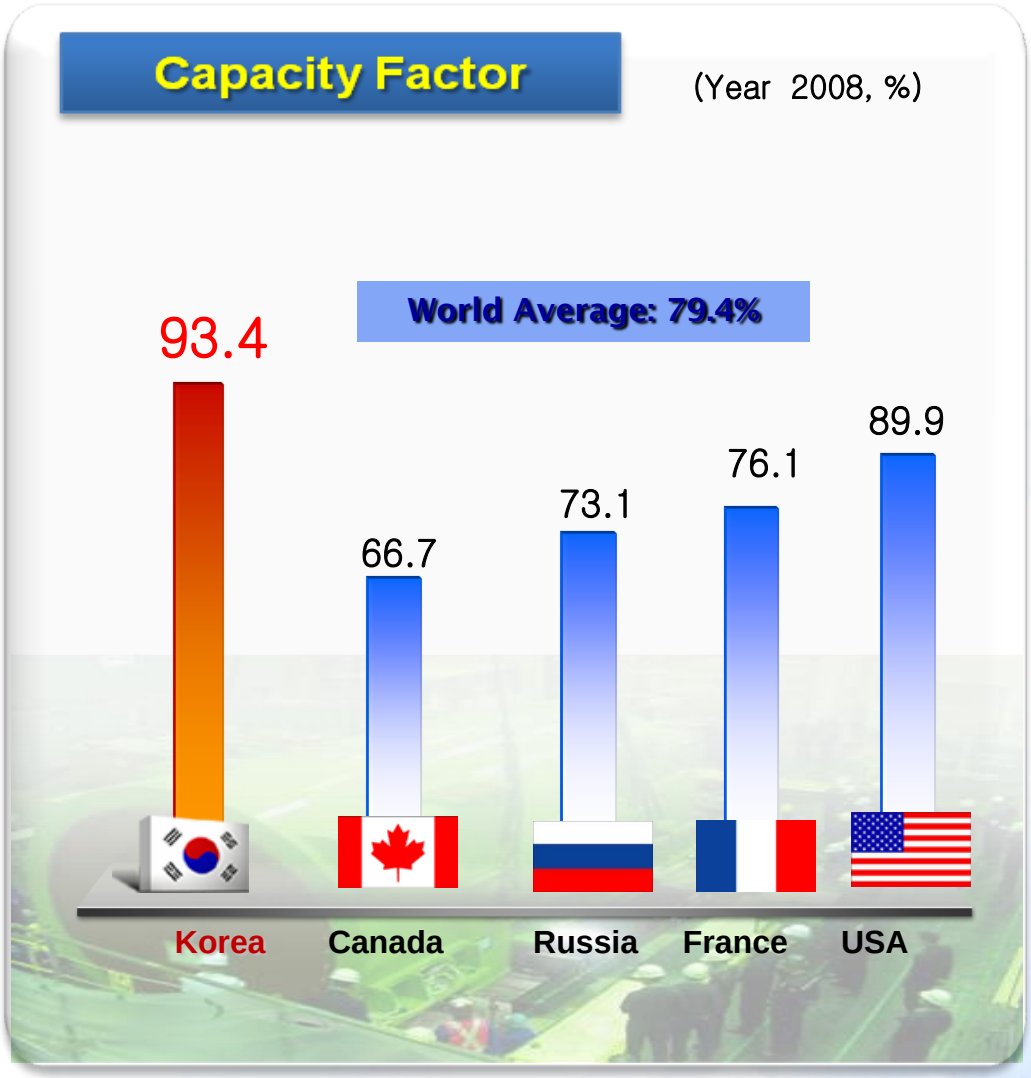
Construction Cost



Operational performance

Capacity Factor

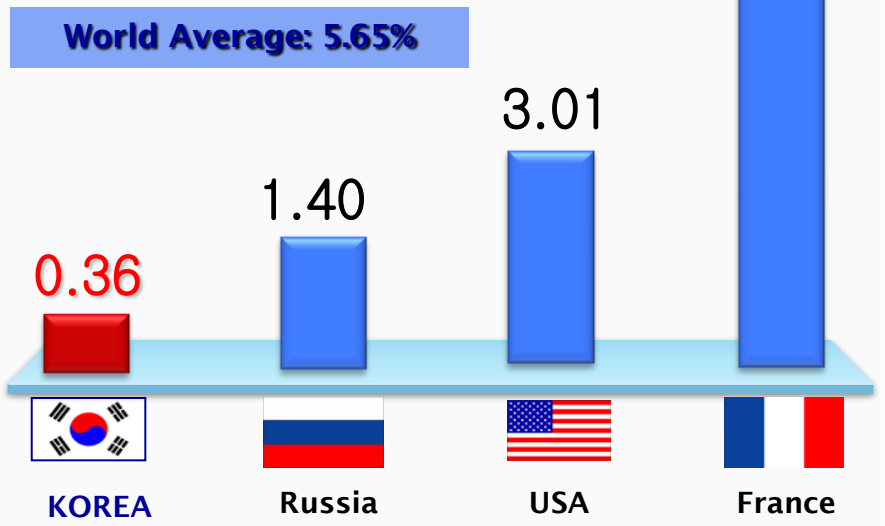
(Year 2008, %)



※ Source: *Nucleonics Week* (2009. 3)

Unplanned Capability Loss

(Year 2008, %)



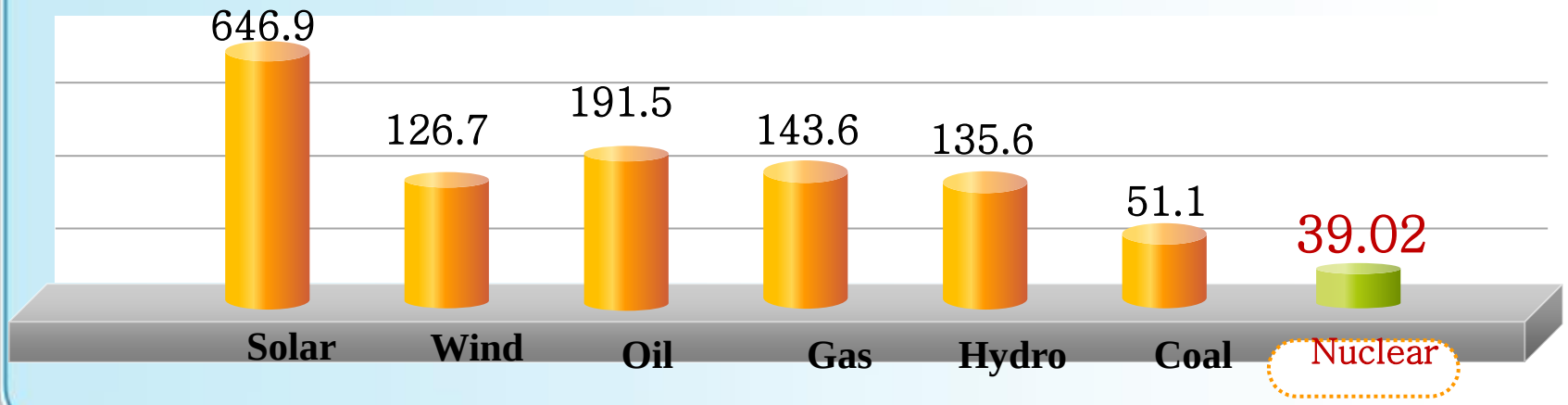
※ Source : IAEA

Accomplishments of nuclear power

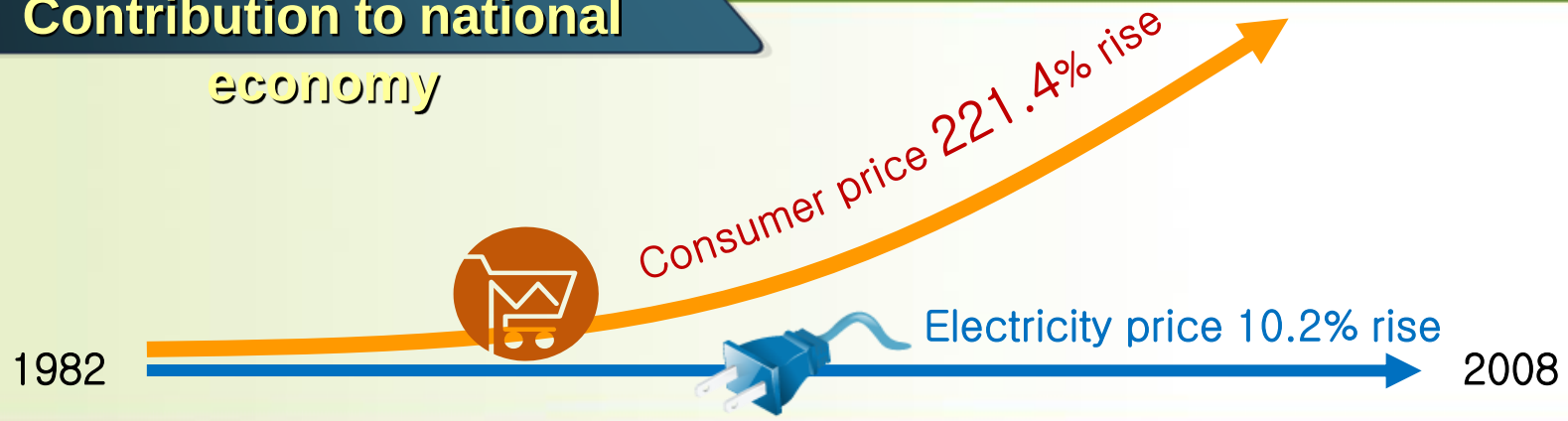
Economical efficiency

- Sales price(KRW/kWh) : Nuclear is the cheapest

(year 2008)

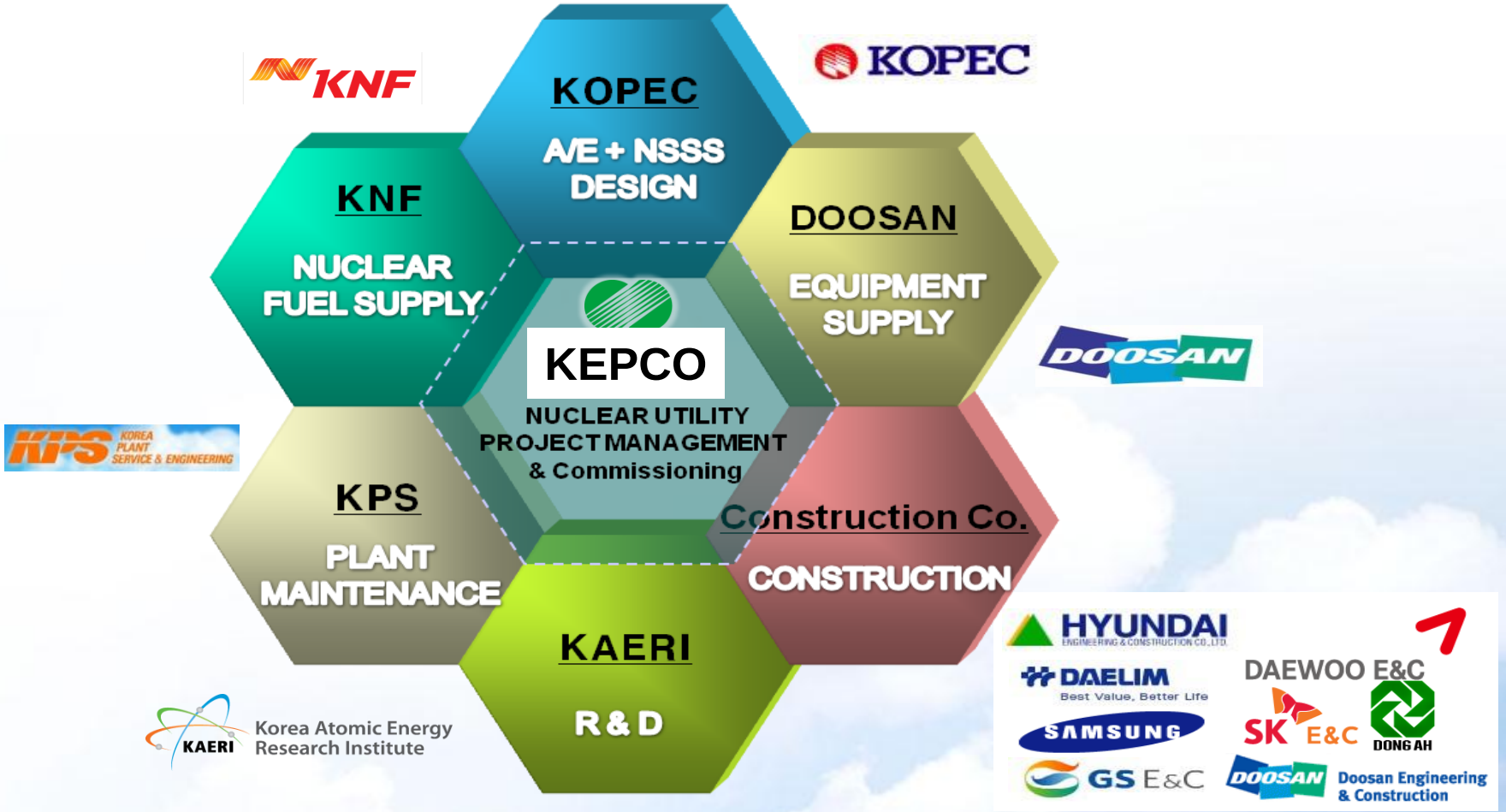


Contribution to national economy



4.4 Nuclear Industry commercial competitiveness

Electric Power Group Cooperation Council



Doosan Heavy Industry (Manufacturing)

5. Lessons learned

- Anti-nuclear movements since 1988
- 20 years for LM radwaste repository site
- Nuclear armed North Korea
  - KEDO LWR mothballed after ~$1 bil
- Spent fuels keep pilling up

Key Factors for Success

- Consistent pro-nuclear government policy
  - 4 Presidents' personal support
- Standardization with repeat plants
  - 12 KSNP 1000 MWe PWRs built by EPGCC
  - Licensing process , supply chains streamlined
- National lab for early technical self-reliance
  - KAERI on NSSS system design with C-E
- Powerful utility with proven management
  - KEPCO and EPGCC ready for export market
- "*Two-out-of-three*" mentality
  - Hard work + inter-personal skills

What are the lessons?

- **For the nuclear majors:**
  - **Chernobyl fallout**
  - **Less secrecy, competition**
    More cooperation, networking
- **For developing countries:**
  - ***"Can Do"* spirit, "2 out of 3"+ 1**
- **For NPP market:**
  - **Market economics over politics**

"Nuclear Silk Road builders"

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