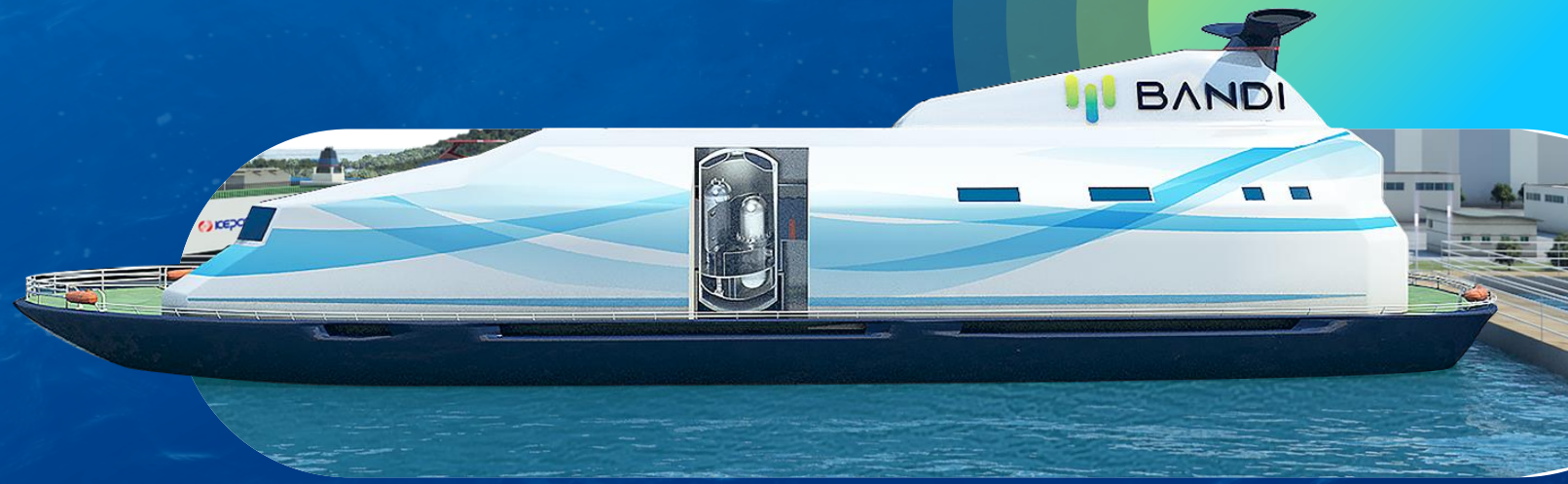
해양 SMR BANDI
기술개발 현황 및 사업화 추진 계획



한국원자력학회 워크샵

2024. 10. 23. 창원

이 병 진

Contents

NO.1

한기 해양 SMR 개발 배경과 목표

01 SMR 틈새시장

SMR 경제성의 기본은 “대량 생산”

기존 시장에서 타 에너지원과 경쟁하려면, **설계 표준화 & 대량 연속 생산이 필수적**

작은 원자로, 특수 목적 시장에서 새로운 기회를 찾을 수 있어

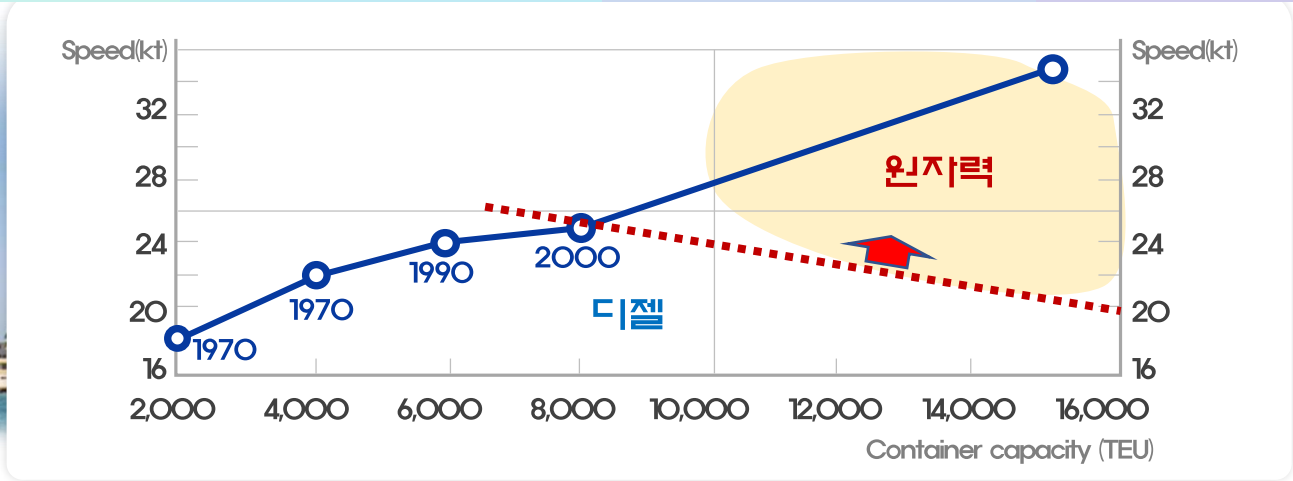
- 무탄소 **분산 전원**
- 무탄소 **산업 공정열**
- 무탄소 **해양 부유식 발전원, 대형상선 추진 동력 …**

02 해양 Net Zero … 원자력으로

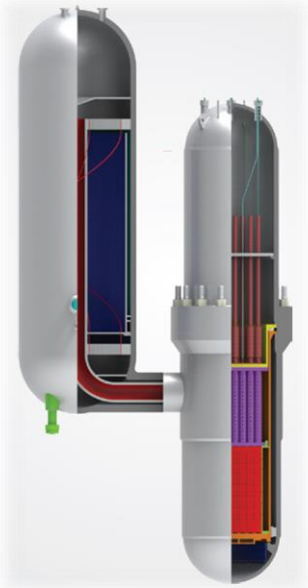
- 국제해사기구(IMO) 탄소감축 로드맵 (2023. 7)

✓ 2050년까지 해양 탄소중립 달성!

* IMO : International Maritime Organization



BANDI™



- 상선 … 좀 더 크고, 좀 더 빠르게… 무탄소로
- SMR, 최적의 대안

03 한기의 선택

기본 원자력 부유식 발전선

원자력 추진 대형 상선 **확대**

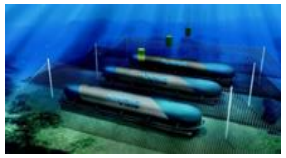
해양 원자력 시스템

착저식

100-1400 MWe

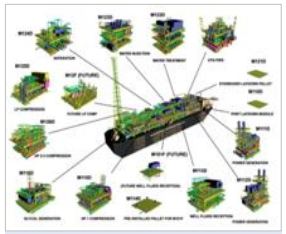
부유식

연안



80-120 MWe

대양



80-140 MWe

선박 추진

40-120 MWe

* KNS 조선해양-원자력 특별위원회, 2015

04 해양 원자력, 최근 동향

- **원자력 발전선**
  - ✓ SMR, 격오지 분산 전원

Rosatom Akademik Lomonosov 운전 개시, 2019.12

Seaborg, FNPP 개념, 2024.05

- **원자력 추진선**
  - ✓ 해운업계, 탄소감축 수단으로 원자력에 대한 관심 고조
  - ✓ SMR, 상용선박 추진동력

IAEA 사무총장 (2024. 6)

IAEA's Grossi: Marine propulsion among potential uses of SMRs

In his recent address to the IAEA's Board of Governors, Director General Rafael Mariano Grossi highlighted commercial marine propulsion as one of the many possible uses of Small Modular Reactors, noting the growing interest of the shipping industry in using nuclear propulsion to cut its carbon emissions.

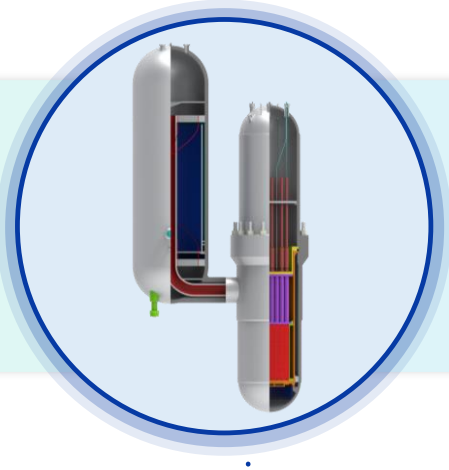
Read more.

NO.2

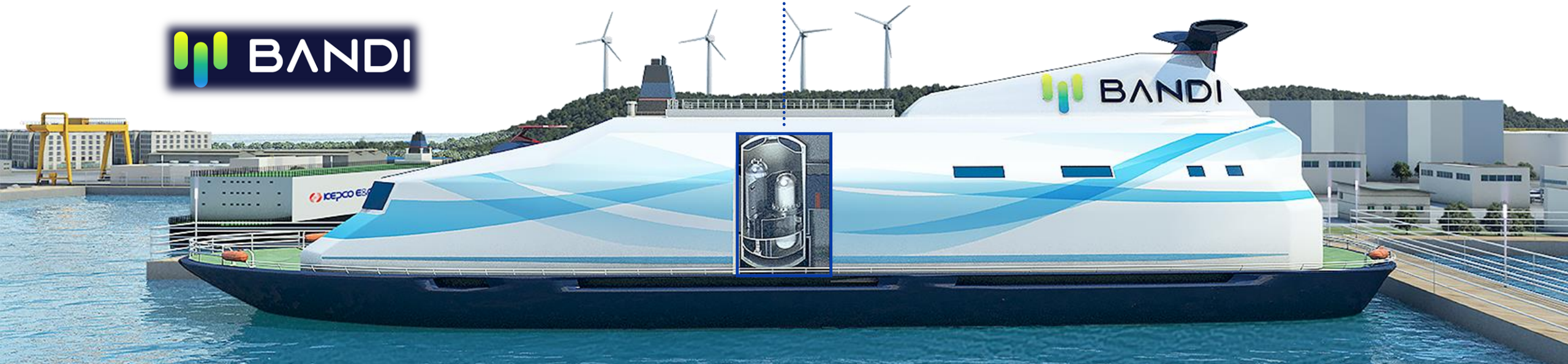
BANDI 개발 내용과 성과

01 BANDI 의 꿈 …

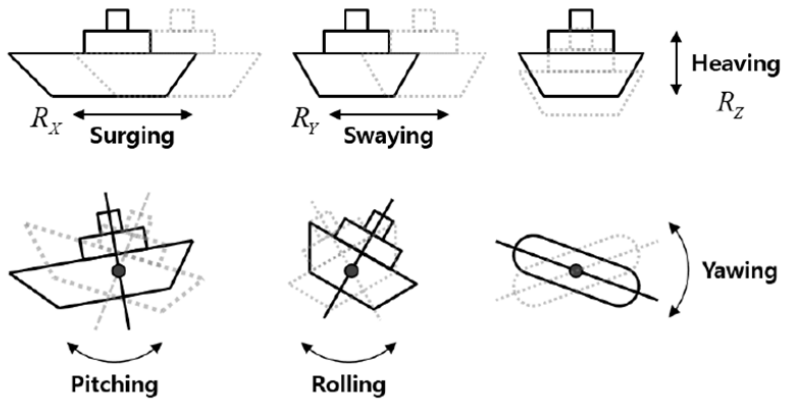
발전선, 대형상선에
깨끗하고, 안전하고, 안정적이고, 경제적인
에너지원 제공

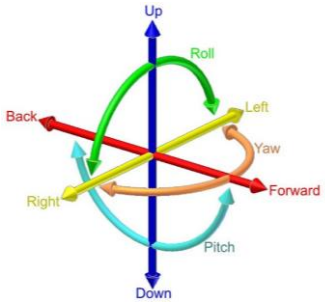


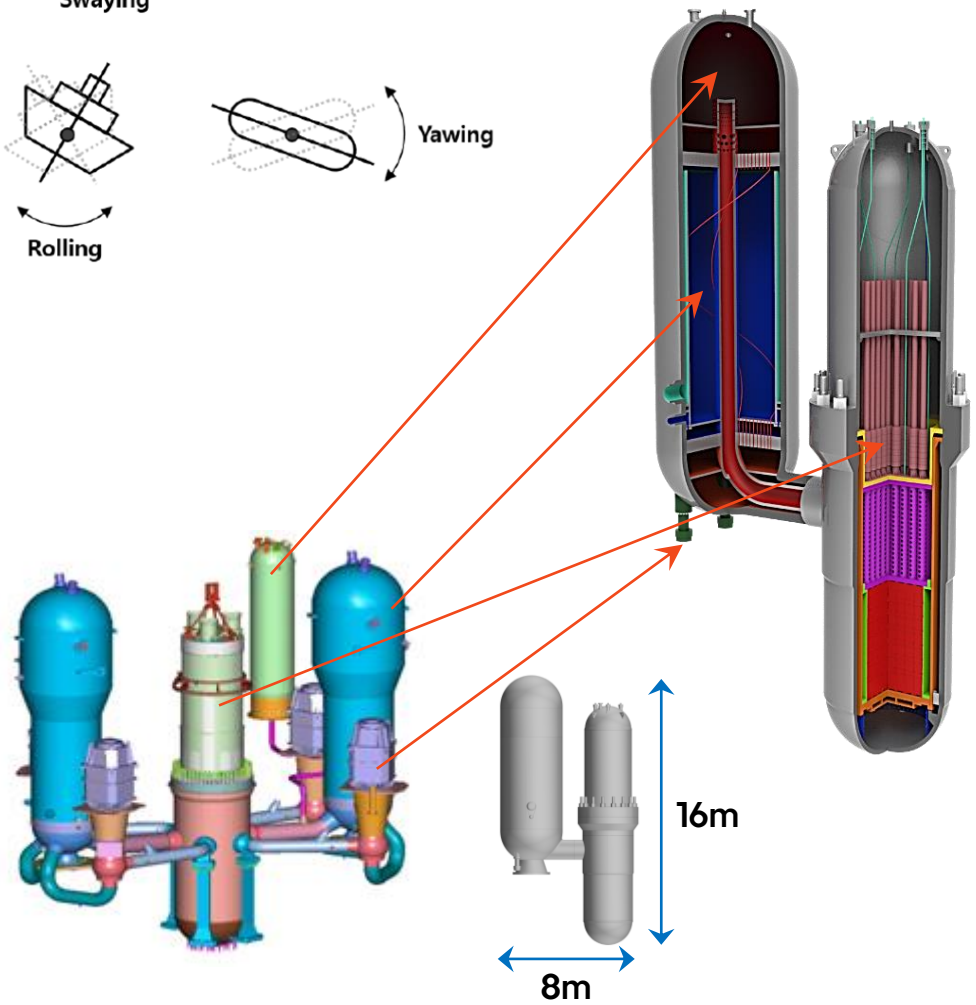
반디 (BANDI)
여름 밤 깊은 숲 까만 어둠을 밝히는 조그만
불빛의 깨끗하고 귀여운 이미지에서 연상



02 BANDI 주요 설계 특성







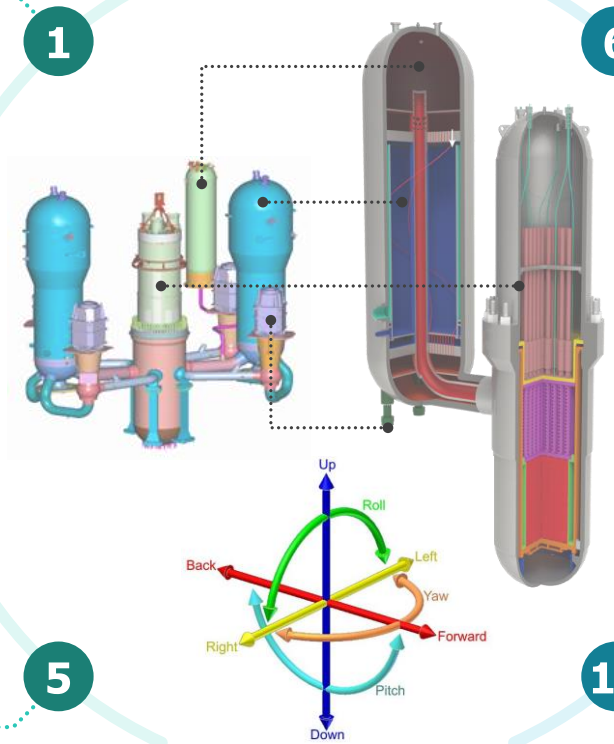
● BANDI-60 (기본형)

원자로	블록형 (반일체형) 가압경수로 ✓ 노즐-노즐 직접 연결
출력 (열/전기)	200 MWt 60 MWe (발전선, 효율 30%) * 선박추진용, 30~40MWe
핵연료 및 노심	17x17 봉형, 농축도 ≤5% UO_2 52다발, 유효노심 높이 2m 재장전 주기 4~5년
반응도 제어	제어봉 (IV-CRDM), MTC & 온도프로그램 가연성독물질 (BP) (필요시) 이차정지 독물질
증기발생기	과열증기 관류형(OTSG) 1대 나선형 전열관 (증기 shell side)
가압기	증기압 제어 (SG 블록 상부 일체형)
냉각재펌프	캔드모터 펌프 2대 (SG 블록 장착)
안전 주입, 잔열 제거	피동 (안전) 능동 (비안전)
해양 환경 설계	6-자유도 경사요동 하중 등
설계 수명	60 년 (부유체 수명 연계 조정 가능)

03 입증 기술 기반 혁신

● 주요 진보 설계 특성

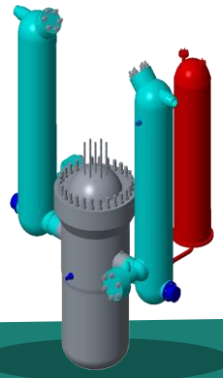
1. **Reactor Block - SG Block**
   nozzle-to-nozzle connected
2. **Soluble Boron free**
3. **In-vessel CRDM**
4. **Top-mounted ICI**
5. **Fully Passive Safety**



6. **Canned-motor RCPs**
7. **Integral pressurizer**
8. **Steel Containment Vessel**
9. **Automatic load following**
10. **Design for Ocean**
    six-degree-freedom motions

04 BANDI의 진화는 진행 중 …

- 단순화, 최적화

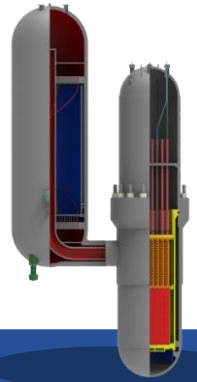


2018

- Semi-integral
- Two-loop
- Boron free
- CEDM, ex-vessel

2020

- Semi-integral
- Two-loop
- Boron free
- CEDM, in-vessel



2024

- Semi-integral
- One-loop
- Boron free
- ICI, top-mounted
- RCP, canned motor
- SG, superheated steam
- CEDM, in-vessel
- PZR, integrated to SG block

FEEDBACK

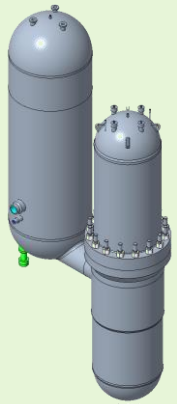
BANDI

NO.3

향후 추진 계획

01 중장기 로드맵, 추진 전략

SMR 기술 역량 강화 ➡ SMR 사업 기회 확대



BANDI

NOW

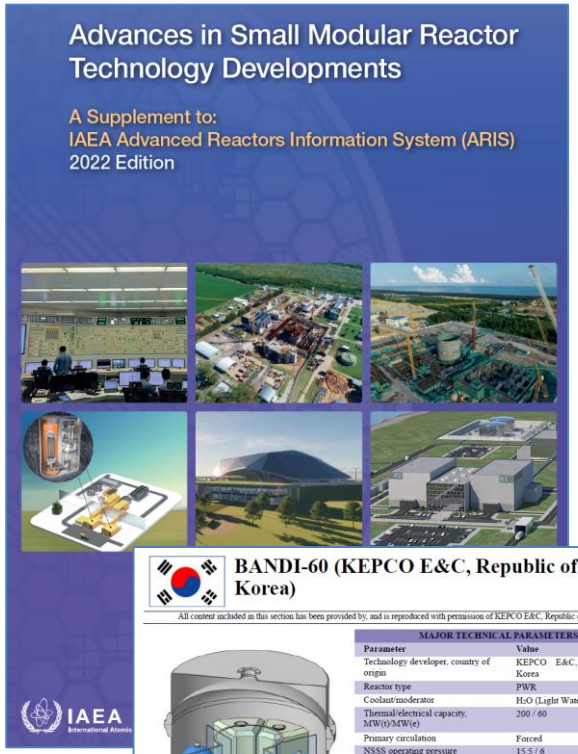
'16~'22	'23~	2yrs	5yrs
준비	개념 설계	기본 설계	표준 설계, 인허가

파생 효과

상용화

- SMART
- iSMR
- Renewables
- What else?

02 외연 확대



BANDI-60 (KEPCO E&C, Republic of Korea)

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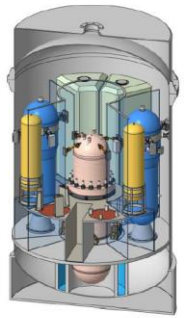


MAJOR TECHNICAL PARAMETERS	
Parameter	Value
Technology developer, country of origin	KEPCO E&C, Republic of Korea
Reactor type	PWR
Coolant/moderator	H_2O (Light Water)
Thermal/electrical capacity, MW(t)/MW(e)	200 / 60
Primary circulation	Forced
NSSS operating pressure (primary/secondary), MPa	15.5 / 6
Core inlet/outlet coolant temperature (°C)	290 / 325
Fuel type/assembly array	Oxide / 17×17
Number of fuel assemblies in the core	52
Fuel enrichment (%)	4.95
Refuelling cycle (months)	48~60
Core discharge burnup (GWd/ton)	29.4
Reactivity control mechanism	Rods
Approach to safety systems	Passive safety system
Design life (years)	60
Plant footprint (m²)	6 500
RPV height/diameter (m)	11.2 / 2.8
RPV weight (metric ton)	110
Seismic design (SSE)	N/A
Fuel cycle requirements/approach	4~5 years / Single batch 4.95%
Distinguishing features	Passive Safety System
Design status	Conceptual design

1. Introduction

BANDI-60 is a compact two-loop PWR with two U-tube type steam generators. KEPCO E&C focuses on deploying a floating nuclear power plant in the sea. BANDI-60 is designed for niche markets, for instance, distributed power and heat supply to remote communities, desalination, and hybrid energy systems with renewables, through a collaboration with marine and shipbuilding industries.

Typical Plant Layout

2. Target Application

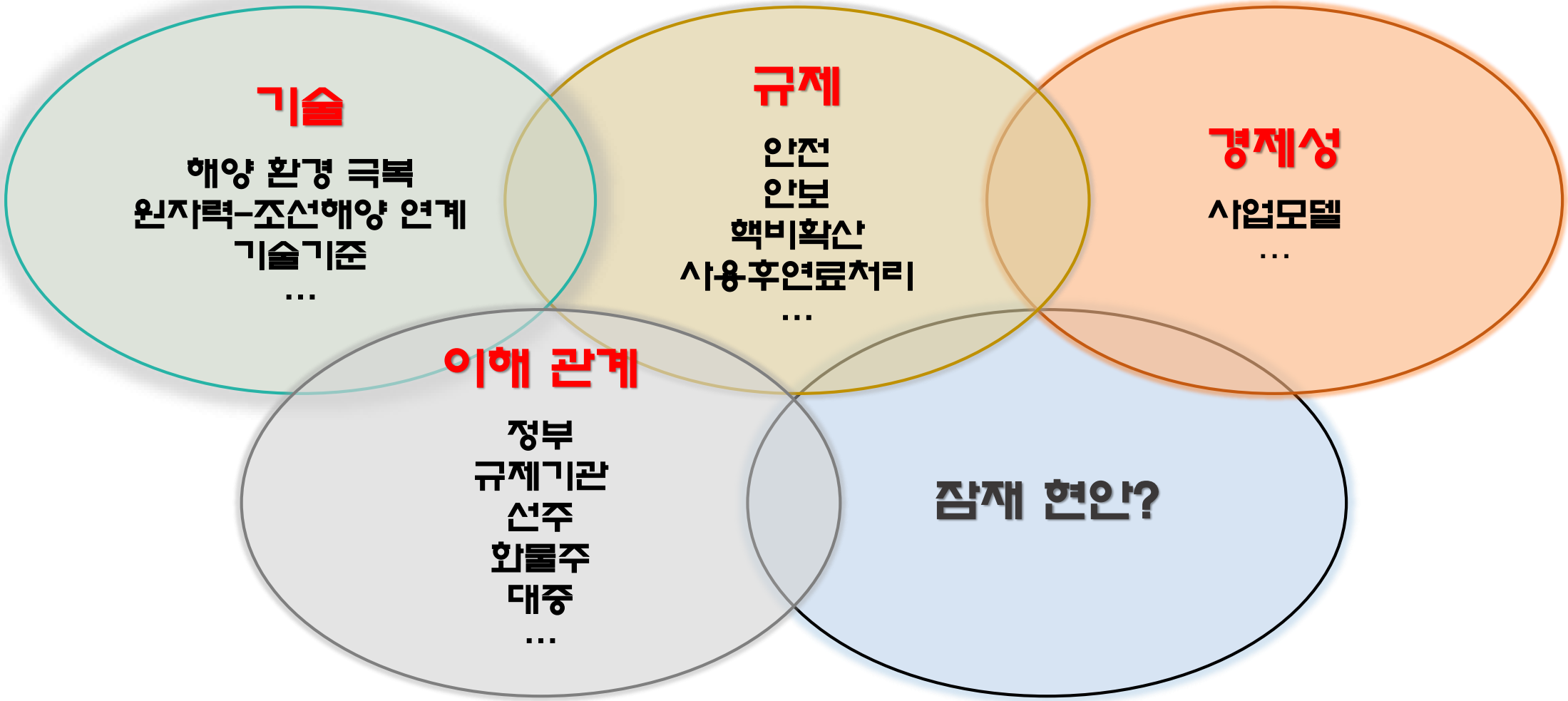
BANDI-60 is designed for off-gid and remote areas such as islands, Arctic area and isolated grid.

3. Design Philosophy

The BANDI-60 design adopts technology innovations developed in-house from 2013, such as the in-vessel control element drive mechanism (IV-CEDM), soluble boron-free (SBF) design and operation, and the Top-Mounted In-Core Instrumentations (TM-ICI). The CEDM inside of reactor pressure vessel will eliminate control element ejection accident. BANDI-60 is designed to operate at soluble boron-free conditions to simplify the design, operation and maintenance of nuclear reactor.

03 극복해야할 난제들

- 모든 현안이 중요하고, 상호 밀접히 연계되어 있어



04 원자력 – 조선해양 협력 기반 구축 & 추진

- 공동 설계
- 사업모델 개발
- 인허가 계획 수립 …

KEPCO E&C

KEPCO NF

HD KOREA SHIPBUILDING & OFFSHORE ENGINEERING

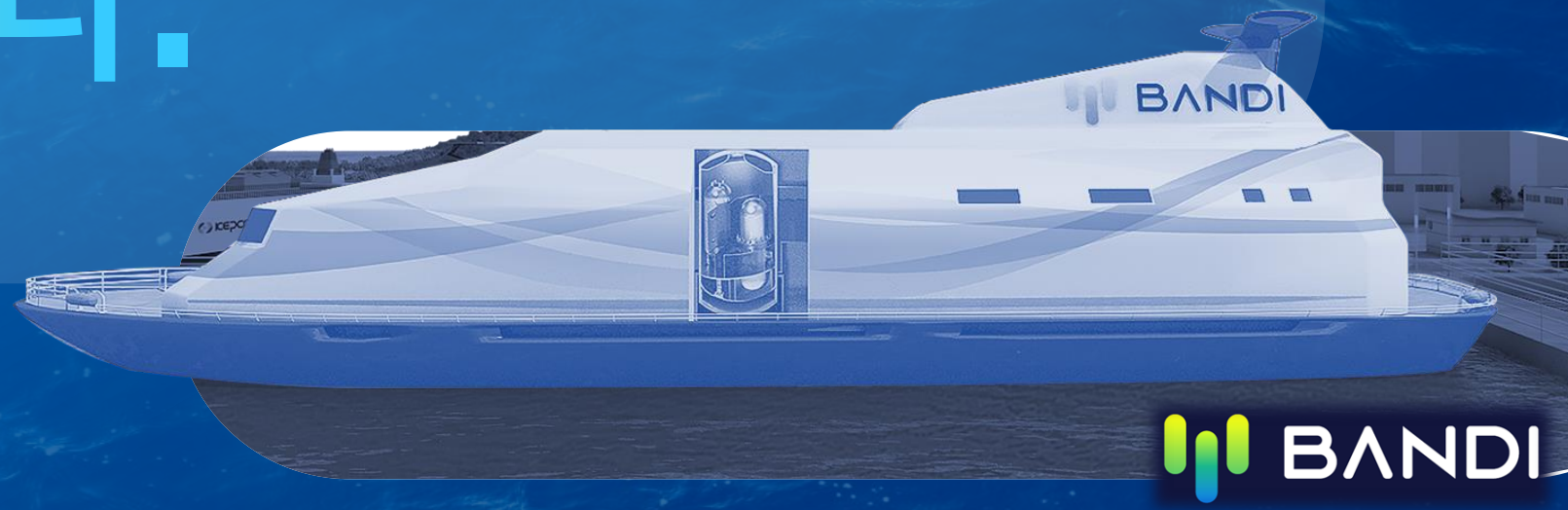
Hanwha OCEAN

Lloyd's Register

ABS

해양 SMR BANDI

감사합니다.



BANDI