Asian Nuclear Safety Network (ANSN)

Regional Workshop on Site Evaluation for Small Modular Reactors (SMRs)

SMRs site selection and evaluation in China

Haikou & Changjiang, China

06 - 10 November 2023

Outline

- Characteristics of SMR
- Overall SMR programme in China
- Regulatory framework for SMR site
- Progress in the Construction of Changjiang SMR
- Future Opportunities and Challenges for SMR

Characteristics of SMR

01 thermal power below 1000 megawatt and electrical power below 300 megawatt

02 modular design and construction concept, as well as passive safety technology

03 higher inherent safety feature, shorter construction period, and application flexibility than third-generation PWR

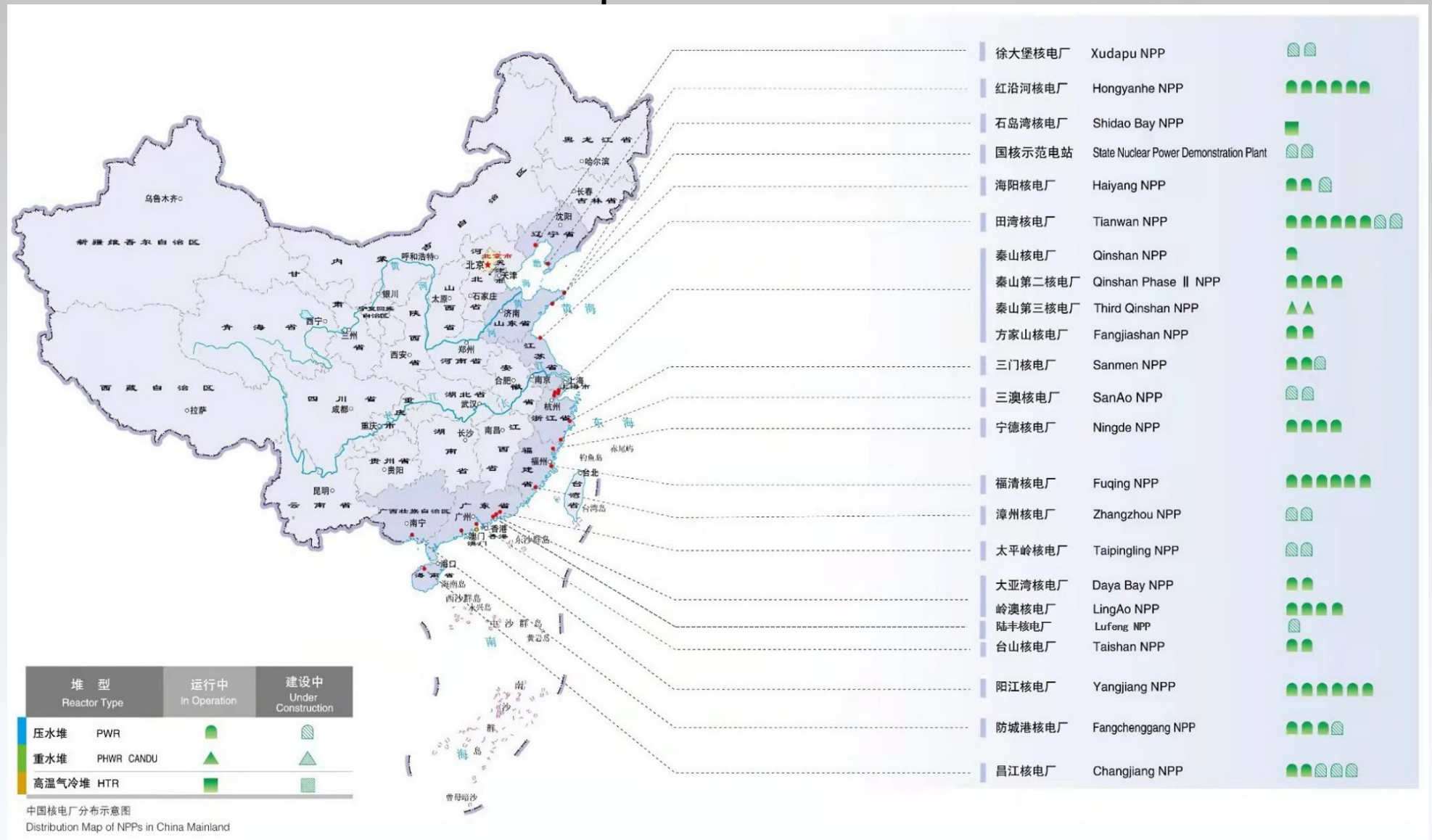
04 small, and its thermal energy storage during normal operation is small. It has less decay heat after shutdown

05 meet the needs of special field applications, such as thermal power supply

06 thermal supply for cities or industries, seawater desalination, hybrid energy,

Overall SMR programme in China

- **By the end of Oct. 2023（total）**
  - 19sites
  - 55 units in operation
  - 24 units under construction



Overall SMR programme in China

- **By the end of Oct. 2023**
  - 12 sites
  - 24 units
  - 22.807 GWe total installed capacity

- **Units type**

  PWR:
  - 10 HPR1000
  - 4 VVER1200
  - 2 CAP1400
  - 4 CAP1000
  - **1 SMR**

NPP (under construction)	UNIT	RATED POWER
Haiyang	Unit 3	1x1253 MWe
Fangchenggang	Unit 4	1x1187 MWe
Tianwan	Unit 7&8	2x1265 MWe
Sanmen	Unit 3	1x1251 MWe
Zhangzhou	Unit 1&2	2x1212 MWe
State Nuclear Power Demonstration Project	Unit 1&2	2×1534 MWe
Taipingling	Unit 1&2	2x1202 MWe
Changjiang	**SMR 1** Unit 3&4	**1x125 MWe** 1x1197 MWe 1x1200 MWe
Sanao	Unit 1&2	2x1210 MWe
Xudapu	Unit 1,3&4	1x1253 MWe2x1274 MWe
Lufeng	Unit 5	1x1200 MWe
Lianjiang	Unit 1	1x1253 MWe

Overall SMR programme in China

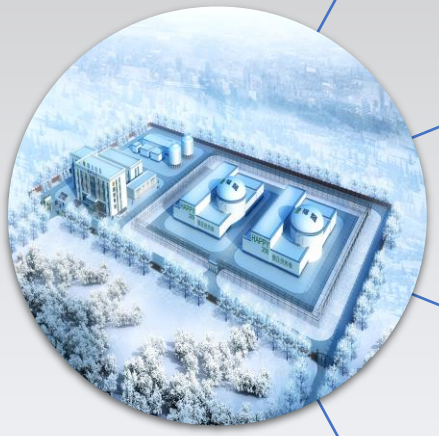
中核集团 CNNC

中广核 CGN

国家电投 SPIC

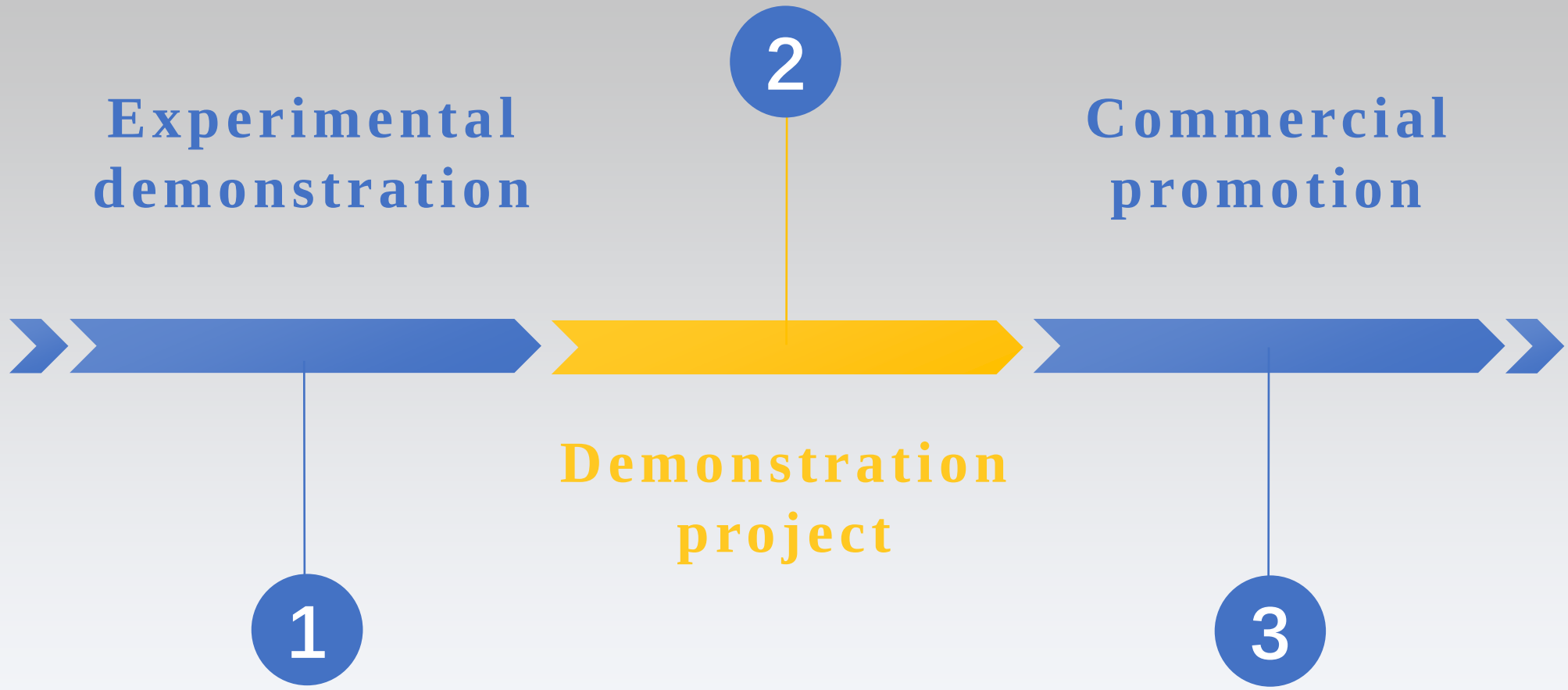
中国华能 CHINA HUANENG

Overall SMR programme in China

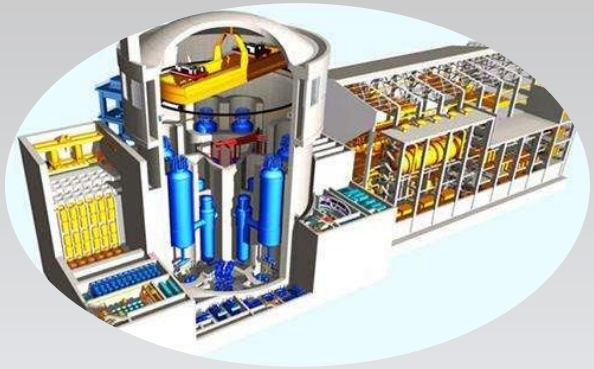


- Light-water reactor
  - Small PWR
  - Small BWR
- HTGR
  - Fourth generation reactor
- Liquid metal reactors
  - Fourth generation reactor
- Molten salt reactors
  - Fourth generation reactor

Overall SMR programme in China

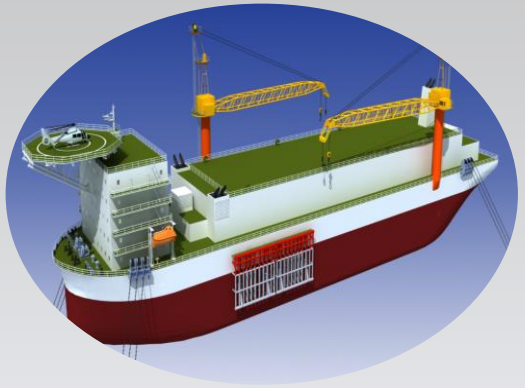


Overall SMR programme in China

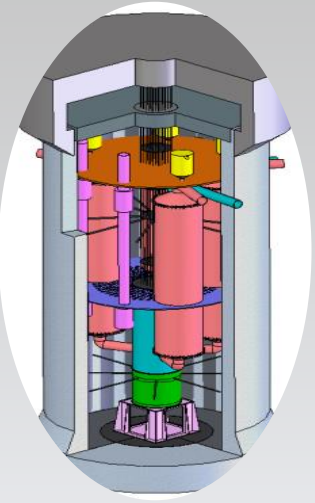


High Temperature Gas Cooling Reactor

ACP100



Floating reactor



Pool reactor

Overall SMR programme in China

ACP100

CNNC

- Adopting an integrated PWR technology route with an output power of 125 megawatts
- Based on existing PWR technology and adopts a validated passive safety system
- The first reactor demonstration project is carried out at the Changjiang Nuclear Power Plant in Hainan
- The construction design of ACP100 project is near completion. The Preliminary Safety Assessment Report (PSAR) was completed in 2018.

Overall SMR programme in China

CAP200

SPIC

- Passive pressurized water reactor with an output power of 200MWe
- Based on over 45 years of technical research and development experience and over 20 years of safe operation experience
- The conclusion of research and development experience and achievements in the AP1000 unit and CAP1400
- Absorbing the lessons learned from Fukushima accident and taking strengthened measures, the conceptual design was completed in 2015

Overall SMR programme in China

DHR400

CNNC

- Pool reactor with a thermal power of 400MW
- Working at low temperature and atmospheric pressure. Incorporating inherent safty features
- The water storage in the pool is large, with high thermal inertia, long response time, and robust to accidents
- The possibility of core melting is very low, eliminating the possibility of a large amount of radioactive material release

Overall SMR programme in China

ACPR50S

CGN

- A small modular offshore floating reactor
- Aims at inherent safety feature and adaptability, modular design, and multi-purpose applications
- Provide a comprehensive supply of heat, electricity, and freshwater for marine resource development activities, energy supply to islands

Regulatory framework for SMR site evaluation

- The commonality between SMR and large PWR：
- 3 basic safety functions
  - Controlling reactivity
  - Removing heat from the core and spent fuel
  - Containing radioactive materials, and limiting accident releases
- SMR is a miniaturization of large PWR
- SMR site evaluation mainly refer to large PWR

Regulatory framework for SMR site evaluation

The safety regulations for site evaluation（HAF101）

Safety guidelines（HAD）

- Earthquakes（HAD101/01）
- Atmospheric dispersion（HAD101/02）
- Population distribution（HAD101/03）
- External human events（HAD101/04）
- Hydraulic dispersion（HAD101/05）
- Hydrogeology（HAD101/06）
- Site survey（HAD101/07）
- riverside plant site flood control（HAD101/08）
- coastal plant site flood control（HAD101/09）
- extreme meteorological events（HAD101/10）
- tropical cyclones（HAD101/11）
- foundation safety（HAD101/12）

Applicant:
Format and content of safety analysis report

Reviewer: Standard review plan

Regulatory framework for SMR site evaluation

Basic factors and evaluation objectives that must be considered for site selection

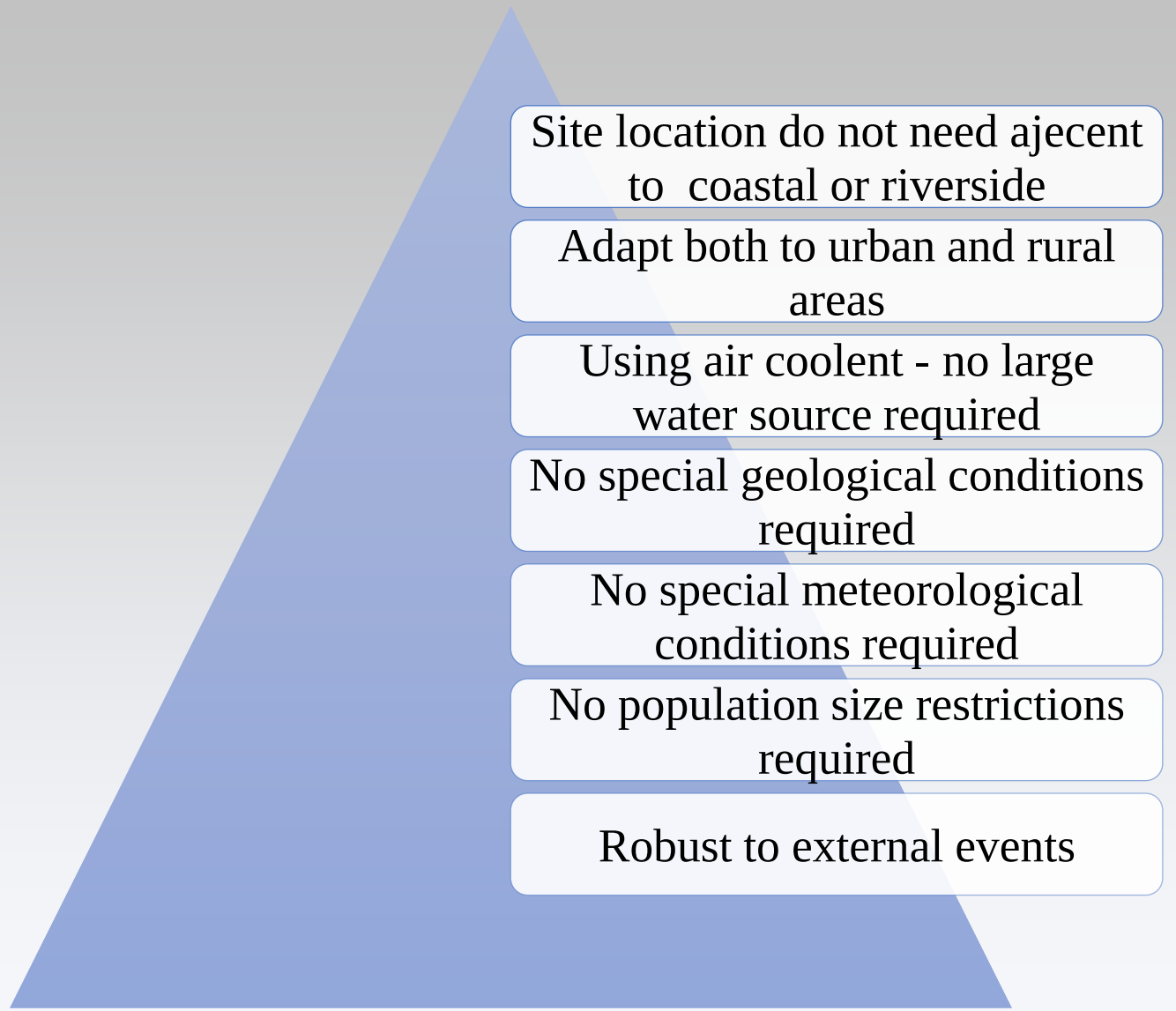
- External natural and human events that may occur in the area where the site is located
- The characteristics of the site and the environment that affect the transfer of radioactive substances to the human body
- The environmental factors related to the implementation of emergency measures

Regulatory framework for SMR site evaluation

Basic criteria for site evaluation

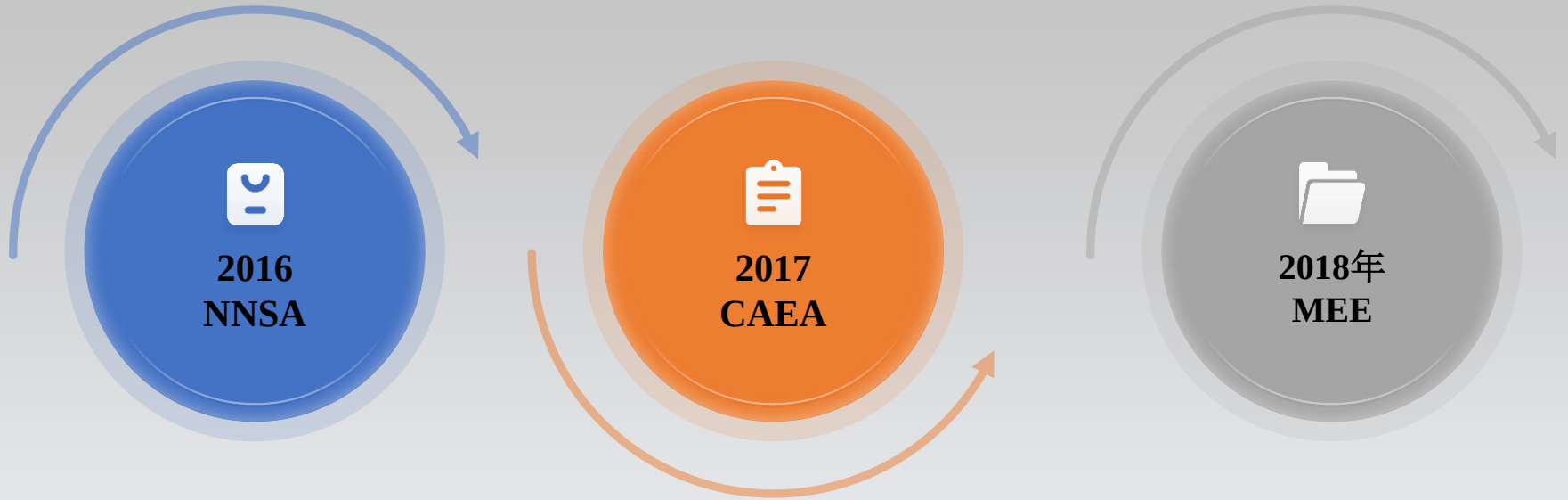
- Follow the basic construction procedures for site selection.
- Investigate and evaluate site features (external natural and human events) that may affect safety, and determine design criteria.
- Investigate the environmental characteristics of areas that may be affected by radiation consequences under normal operating and accident conditions.
- Consider the storage and transportation of new fuel, spent fuel, and radioactive waste.
- Evaluate the potential changes that may occur during the lifespan of the plant site and environmental characteristics that affect safety within the plant site area.

Regulatory framework for SMR Site evaluation



SMRs site selection and evaluation

Regulatory framework for SMR evaluation



Principles for Safety Evaluation of Small PWR Nuclear Power Plants	Guidelines for Small PWR Nuclear Emergency Work on Land	Principles and Requirements for the Classification of Non residential Areas and Planned Restricted Areas for Small NPPs

Regulatory standards and technical systems applicable to SMR are gradually establishing

Regulatory framework for SMR site evaluation

Principles for Safety Evaluation of Small PWR Nuclear Power Plants

- For all important event sequences of design basis accidents and beyond design basis accidents, the effective dose and thyroid equivalent dose that individuals (adults) may receive outside the small PWR nuclear power plant should be lower than the intervention level of concealment and iodine protection, respectively.
- Conditions should be created for implementing off-site emergency simplification or even canceling off-site emergency response.

Regulatory framework for SMR site evaluation

Guidelines for Land Base Small PWR Nuclear Emergency Works

- The recommended scope of the small PWR emergency planning area should not exceed 3 kilometers.

- The specific scope should be proposed by the operating organization after systematic demonstration and scientific assessment, determined according to the prescribed procedures.

Regulatory framework for SMR site evaluation

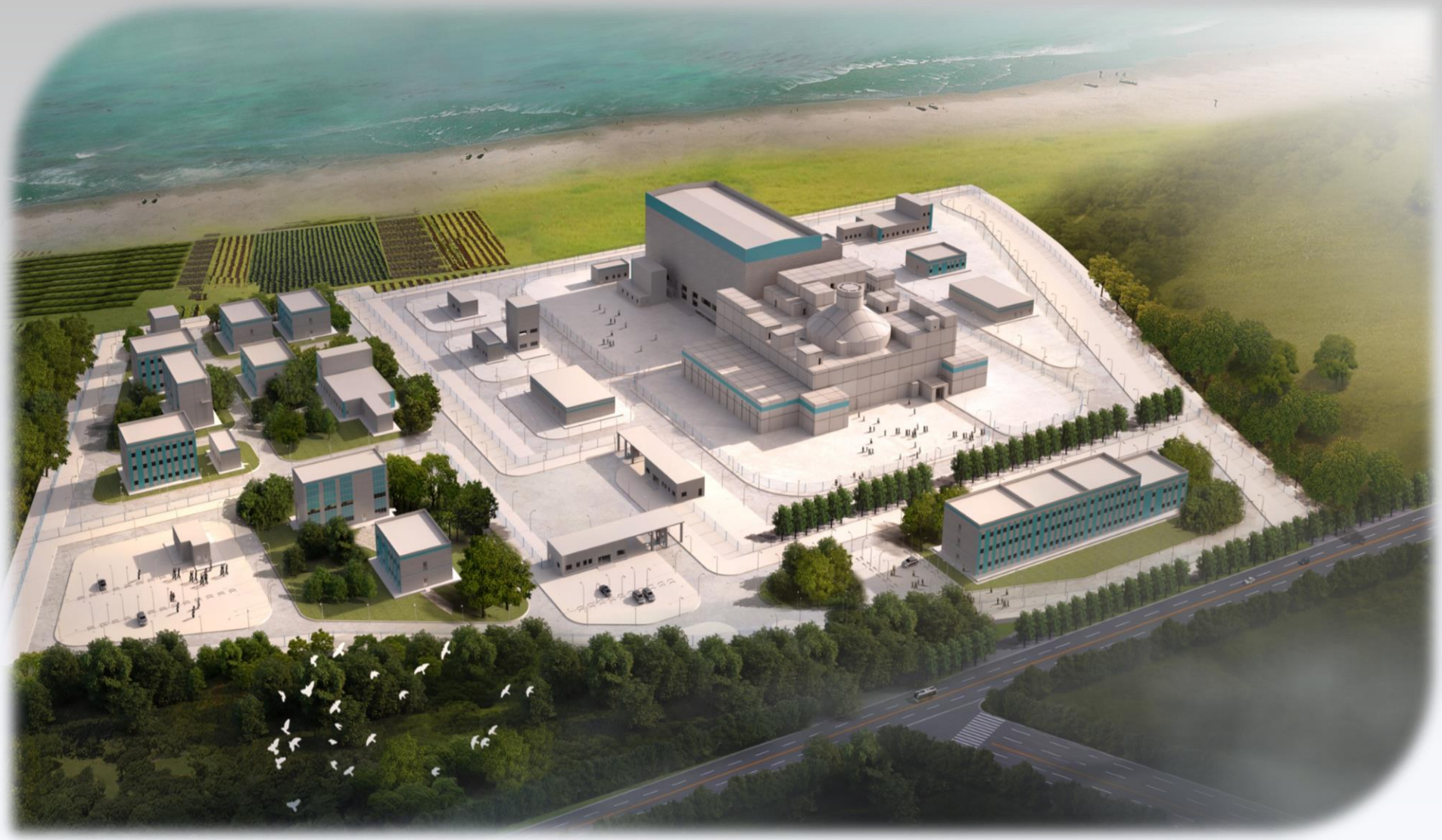
Principles and Requirements for the Classification of Non residential Areas and Planned Restricted Areas for Small NPPs

- The scope of the emergency planning zone and planned restricted area outside the small reaction yard can be reasonably set according to the actual condition.

- Explored the possibility of achieving the "three zones integration" of small nuclear power plant sites, emergency planning zones, and planned restricted areas

Progress in the Construction of Changjiang SMR

☐ Layout of Hainan Changjiang Offshore Plant Site



Progress in the Construction of Changjiang SMR

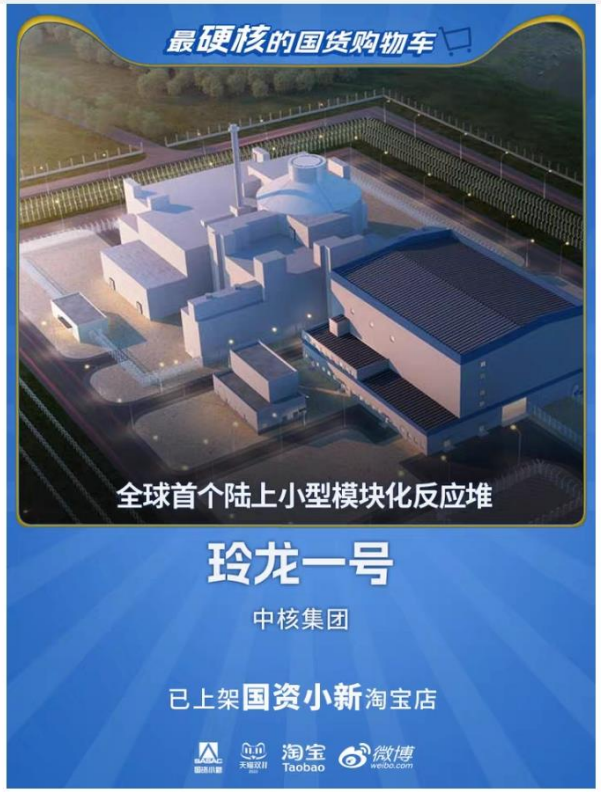
Serial Number	items	Unit	Parameters
Main indicators			
1	Reactor type		IPWR
2	Design life of power plant	Year	60
3	Refueling cycle	Month	24
4	Plant availability	%	＞90
5	Power plant operation mode		Mode A
6	Rated thermal power of reactor core	MWt	385
7	Unit rated power	MWe	~125
8	Thermal efficiency (pure power generation, based on maximum continuous output)	%	＞32
9	Core damage frequency	/Reactor · year	$<10^{-5}$
10	Frequency of release of large amounts of radioactive substances	/Reactor · year	$<10^{-6}$
11	Occupational exposure collective dose	Person· Sv/ Reactor· Year	＜0.5
12	Ultimate Safe Ground Motion SL-2	g	0.30（major equipment） 0.15（others）

Progress in the Construction of Changjiang SMR

Site characteristics

Reviewer domains	Important parameters	Design basis
Populations	Planning restricted areas emergency planning zone	Radius 5km Radius 3km
Seismic	seismic ground motion	The annual probability of exceedance 1.0E-4
Hydrological event	River flood Oceanic flood	Probable maximum flood/The annual probability of exceedance 1.0E-4 Probable maximum storm surge + astronal tide
Meteorological	Rainfall Extreme Wind Snow load Extreme temperature Tornado wind	Probable maximum precipitation 100 years return periods 100 years return periods 100 years return periods The annual probability of exceedance 1.0E-7
Human induced events	Explosion Aircraft crash	According the source item distribution The exclusion annual probability of exceedance 1.0E-7,
Geotechnical	landslide stability of foundation	According to site situation & survey According to site characteristic & engineering survey

Progress in the Construction of Changjiang SMR



Future Opportunities and Challenges for SMR

1. Technological innovation
2. Industry planning
3. Policy guidance
4. Public communication
5. International cooperation

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Thanks for Your Attention

Questions & Comments