Multiple applications of Linglong-1 SMR in the field of district heating and desalination

Nuclear Power Institute of China

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CONTENTS

Background

（1-1）What is Small Modular Reactor (SMR) ?

- SMR is one kind of newer generation reactor designed to generate electric power up to 300 MW, whose components and systems can be shop fabricated and then transported as modules to the sites for installation.

Background

（1-2）What is Small Modular Reactor (SMR) ?

- Adopting modular design and construction concepts, passive safety technology.
- Can reach large power by several modular combination.
- Can be used in different places and different condition.

Background

（2）Challenges Increasing the large NPP power

- Industry capacity and transportation
- Marginal effect of the economy by increasing power
- Difficulty in application of passive technology
- Huge overnight investment
- Not flexibility for different using

Background

（3）Non electrical application nuclear energy and needs of developing countries for nuclear electricity

In 10 to 20 years，70% of the energy consumption in developing countries is non-electricity application, such as heat and transportation.

Background

（4）Improving economic by modular design and constriction

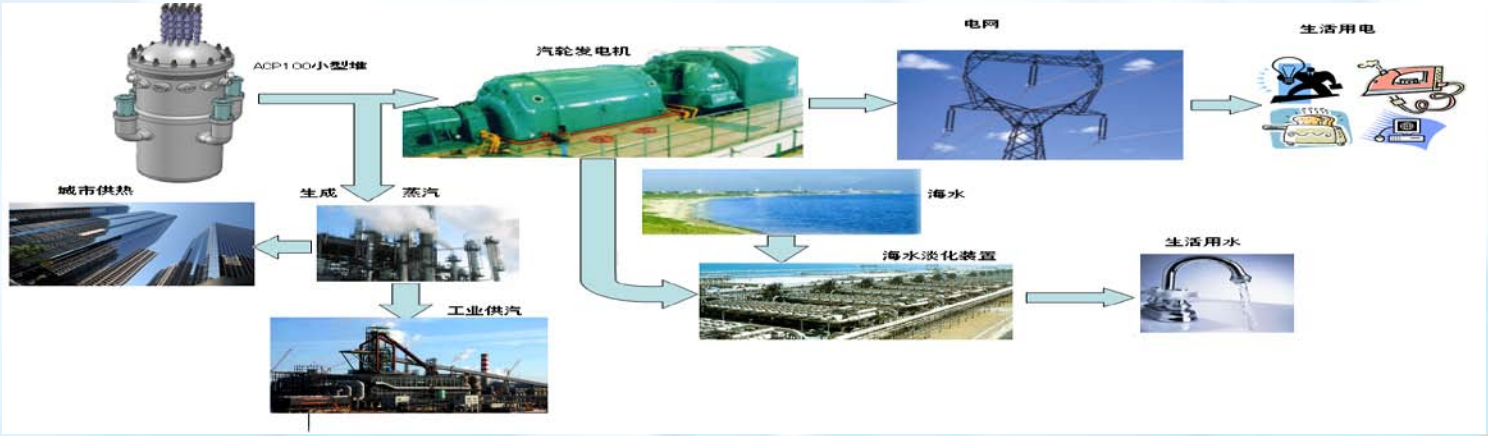
- Not like that of large NPP, SMR achieves its economic by simplify modular design and increase number of the modular.

（5）Advantage for safety

- SMR with lower power, lower residual heating, suitable for passive safety facilities application.

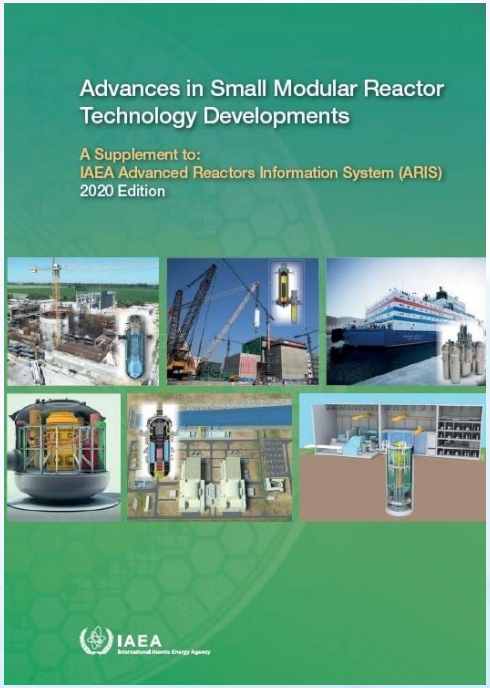
Background

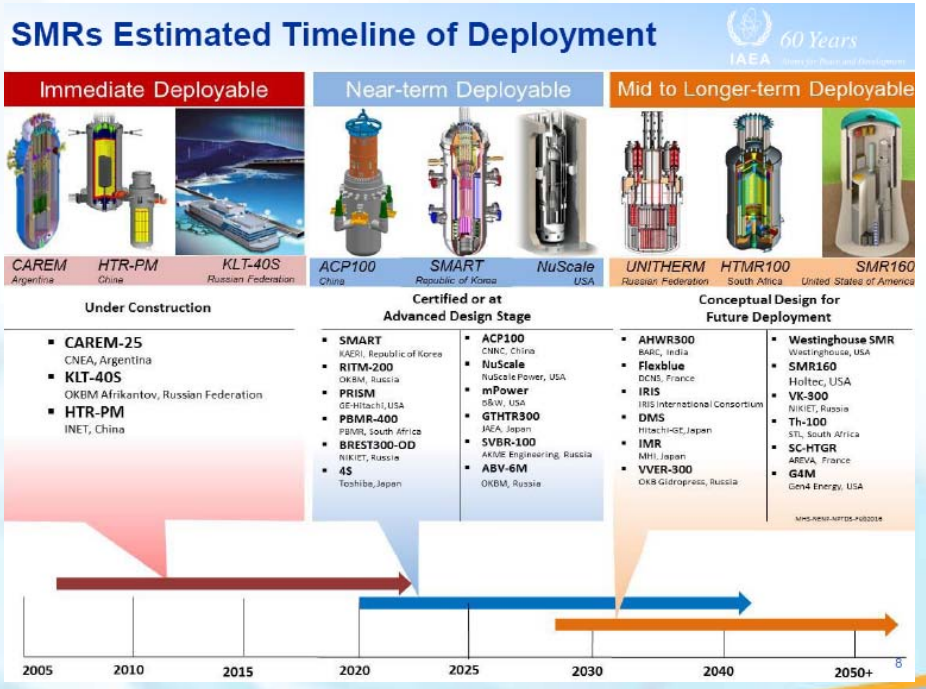
- *SMR is suitable for small electricity grid, district heating, process heating supply, seawater desalination. According to different condition, different countries have different goals.*



Background

- **Main developed and innovated SMR in different countries**
  - **2020 SMR book gives 72 reactors in 18 countries, 1/3 are PWR, and most of them are integrated reactor**





Introduction of ACP100

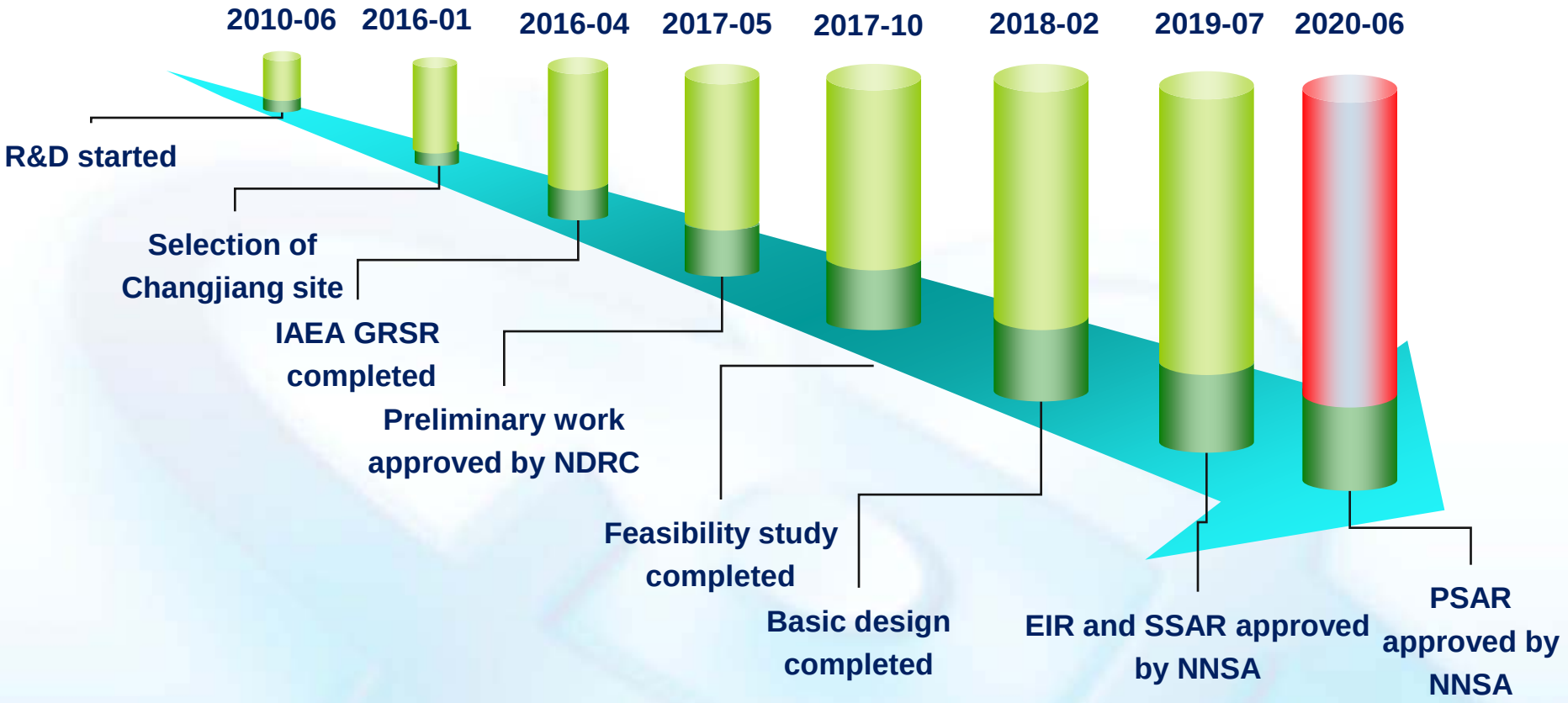
- *CNNC SMR, named ACP100, is an innovative PWR based on existing PWR technology , adapting "passive" safety system and "integrated" reactor design technology*

- *CNNC stared R&D on ACP100 from 2010*

- *The modular design technique is used to control the product quality and shorten the site construction period.*

Introduction of ACP100

Roadmap of ACP100 development



Design parameters of ACP100

Main design parameters

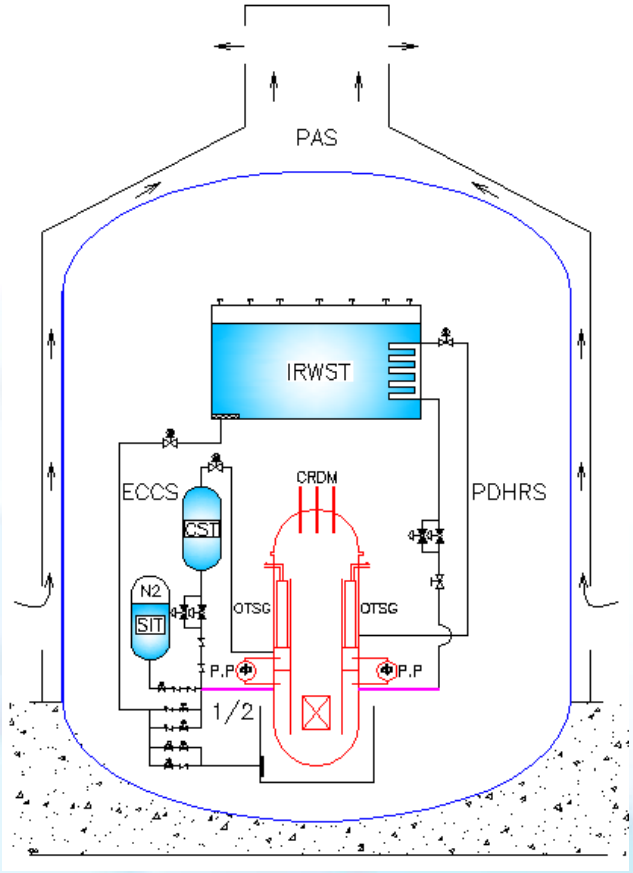
ACP100

Thermal power	385MWt
Electrical power	~125MWe
Design life	60 years
Refueling period	2 years
Coolant inlet temperature	282 ℃
Coolant outlet temperature	323 ℃
Coolant average temperature	303 ℃
Best estimate flow	10000 m^3/h
Operation pressure	15MPaa
Fuel assembly type	CF3 shortened assembly
Fuel active section height	2150 ㎜
Fuel assembly number	57

Design parameters of ACP100

Main design parameters

Fuel enrichment	*4.45%*
Drive mechanism type	*Magnetism lifting*
Control rod number	*25*
Reactivity control method	*Control rod、solid burnable poison and boron*
Steam generator type	*OTSG*
Steam generator number	*16*
Main steam temperature	*>290 ℃*
Main steam pressure	*4MPaa*
Main steam output	*560t/h*
Main feed water temperature	*105 ℃*
Main pump type	*canned pump*
Main pump number	*4*



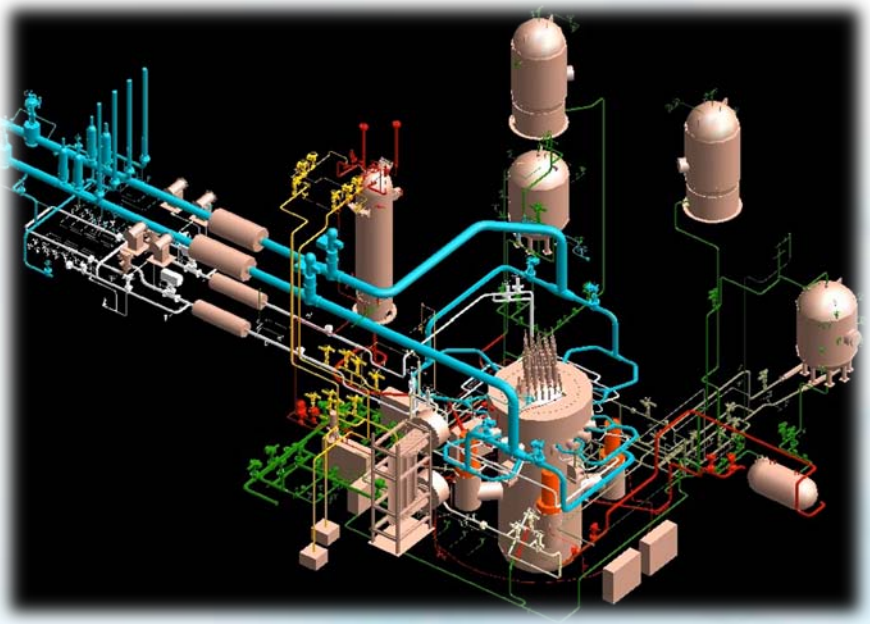
Design parameters of ACP100

Main design parameters

Reactor power-control operation program	primary constant average temperature
Thermal power plant operation model	Base load operation（Mode-A)
Plant design life	60 years
SSE level ground seismic peak acceleration	0.3g
Predicted Core Damage Frequency (CDF)	＜1E-7 Per reactor year
Predicted Large Release Frequency (LRF)	＜1E-8Per reactor year

Design parameters of ACP100

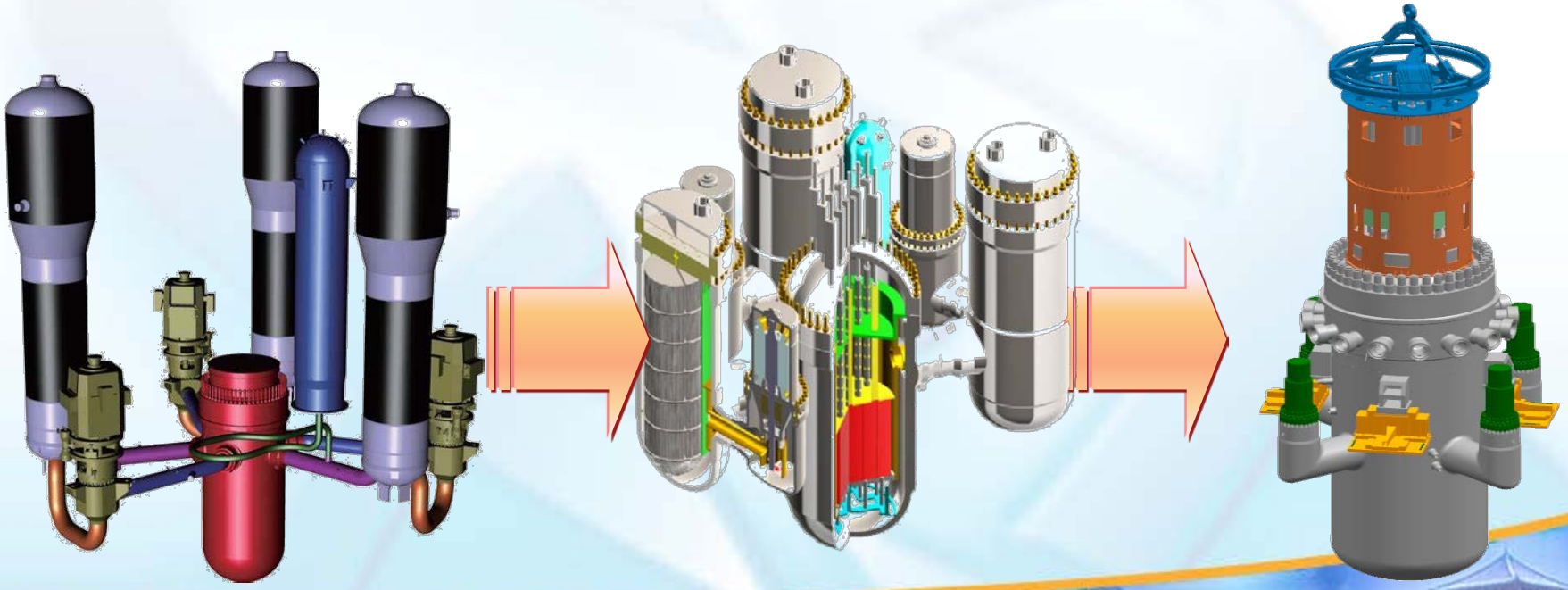
- One reactor with one turbine



Technical Aspects

Integral reactor module

- *The reactor coolant system has been integrated reactor module. The reactor module is consisted of reactor vessel, once-through steam generators, canned motor pumps, reactor internals and integrated reactor head package.*

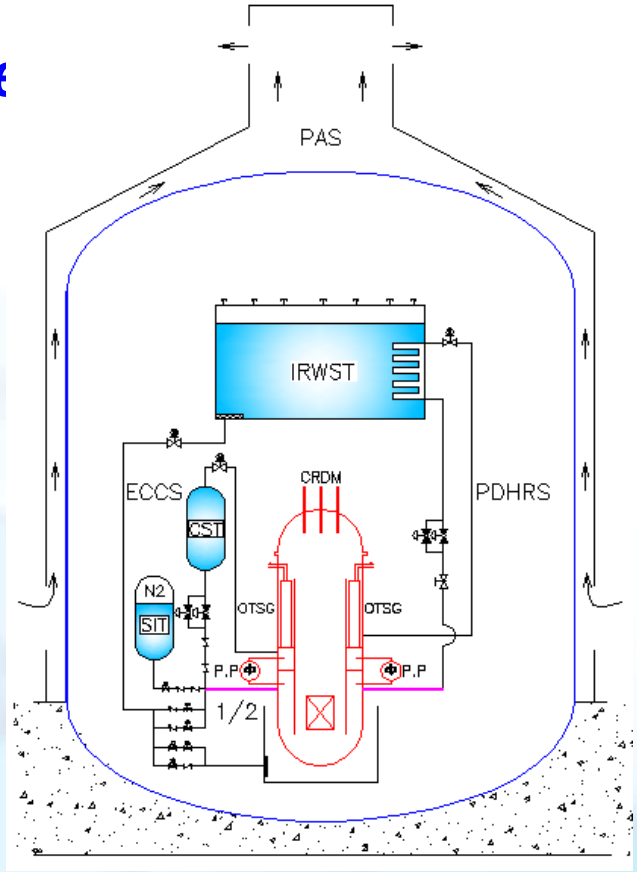


Technical Aspects

Fully passive safety system

ACP100 adopts fully passive safe illustrated in Figure:

- passive core cooling system,
- passive residual heat removal system,
- passive containment heat removal system,
- passive inhabitation system,
- automatic depressurization system,
- passive hydrogen control system.



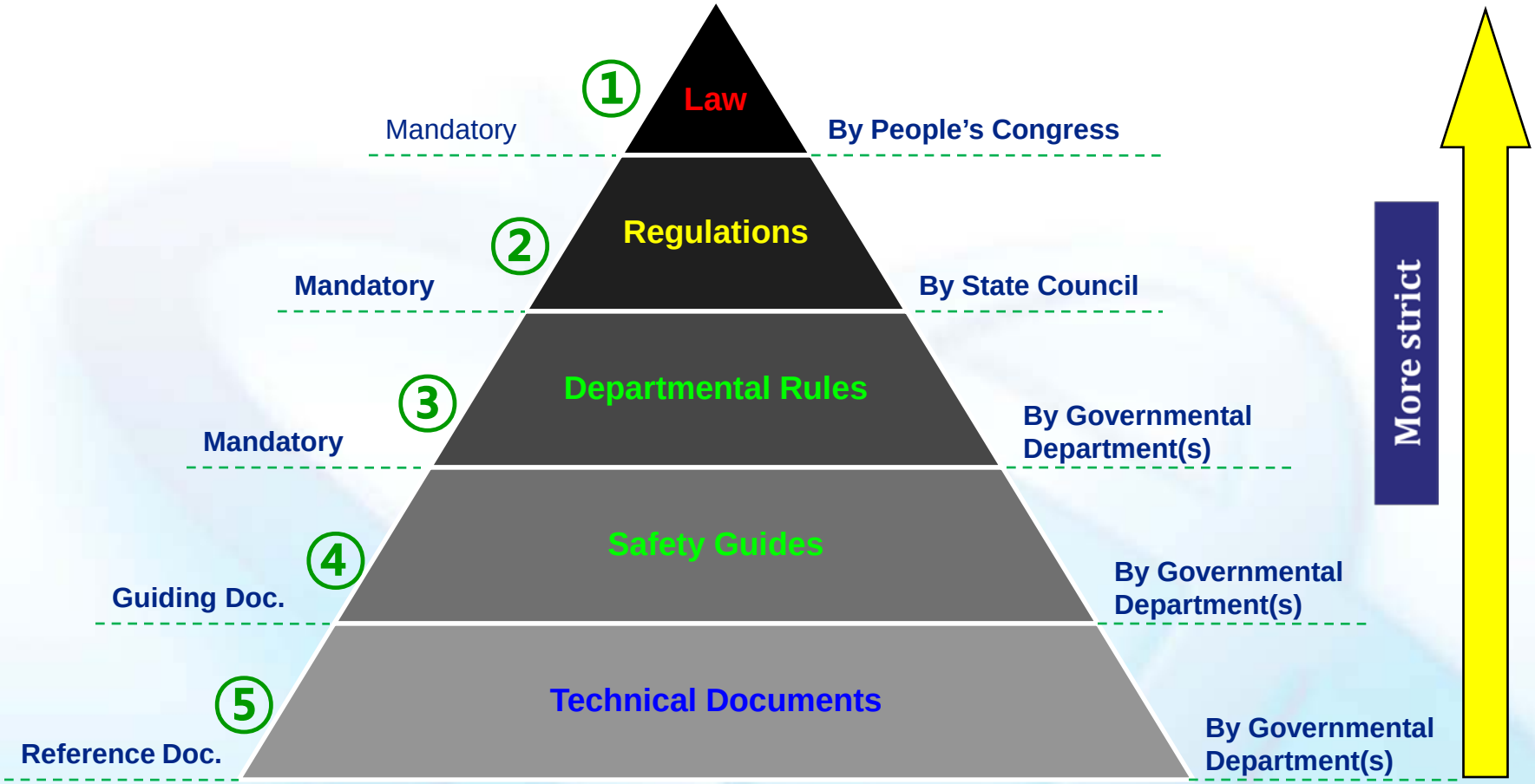
Safety and licensing strategy

Codes and Standards applied by ACP100

- *Level 1, Laws - Issued by the Congress (mandatory).*
- *Level 2, Codes and Regulations - Issued by the State Council (mandatory). Setting up administrative scope, principles, organizations and its' functions etc;*
- *Level 3, Departmental Rules - Issued by governmental organizations (mandatory). Defining the implemental methods based on the Regulations. Setting up nuclear safety objectives and basic requirements; (NNSA)*
- *Level 4, the Guides - Issued by the Governmental organizations (recommendatory). Recommending the methods or procedures to satisfy the safety requirements;*
- *Level Technical documents-Issued by 5, the Governmental organizations (referential).*

Safety and licensing strategy

Codes and Standards applied by ACP100



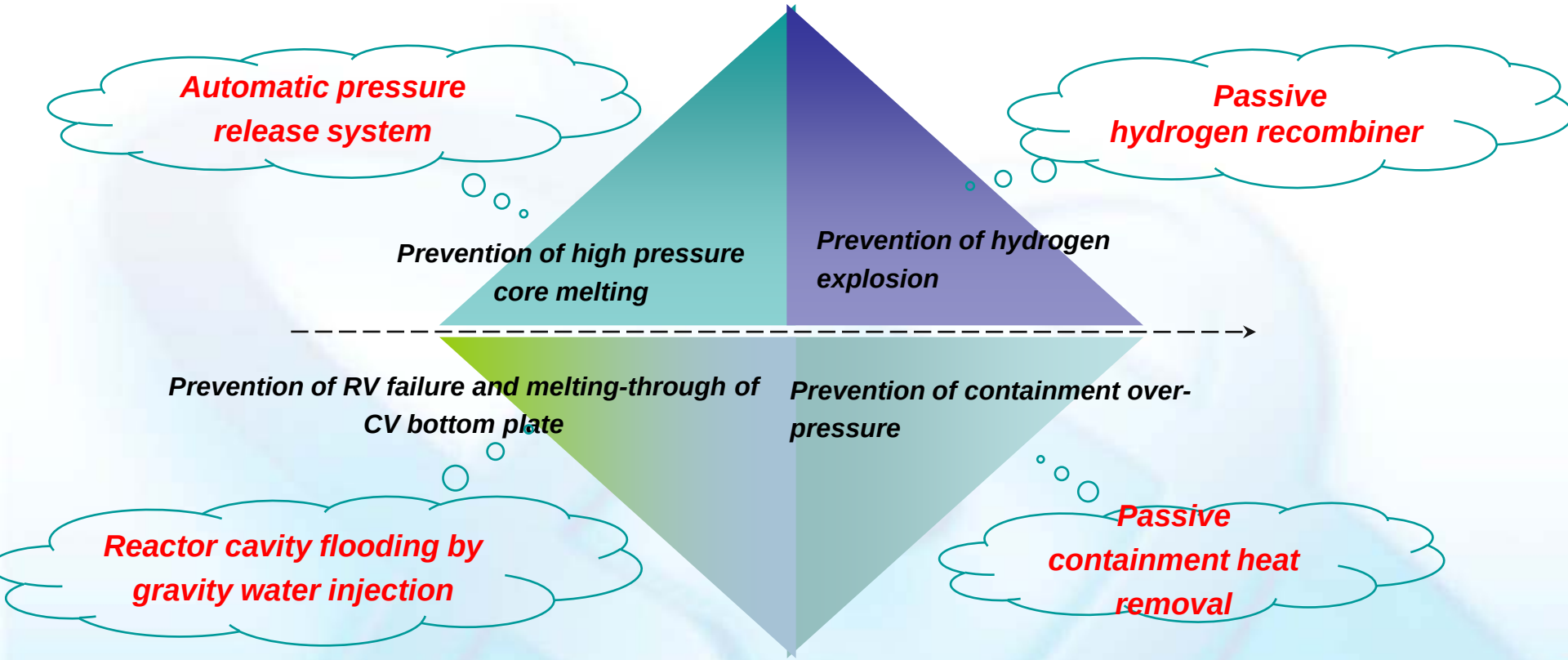
Safety and licensing strategy

ACP100 Safety design conception

- *No active Emergency Core Cooling System*
- *No active containment spray and recirculation system.*
- *No need for operator intervention after accident for 72 hours.*
- *No safety-related emergency AC power.*
- *NSSS integral design minimizes both the probability and impact of design basic accident (DBA).*
- *Mitigate DBA without non-safety system. Emergency planning zone is limited inside the site boundary.*

Safety and licensing strategy

Severe accident prevention and Mitigation measures



Safety and licensing strategy

Third party verification

- *IAEA gave the review comments on ACP100 Generic Reactor Safety Review （GRSR）report on April 22, 2016, the 1st SMR completion of GRSR in the world.*

Safety and licensing strategy

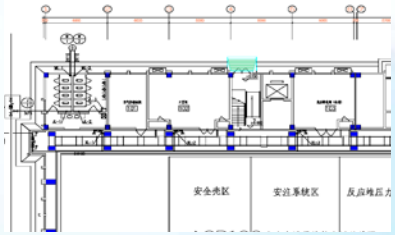
Third party verification

"According to the safety documentation, the ACP100 plant is an innovative design that belongs to the SMR class of NPPs and deploys passive safety features. It can be expected from new designs that they are capable of dealing with extreme environmental conditions and multiple failures to assure that early or large radioactive releases are practically eliminated. "

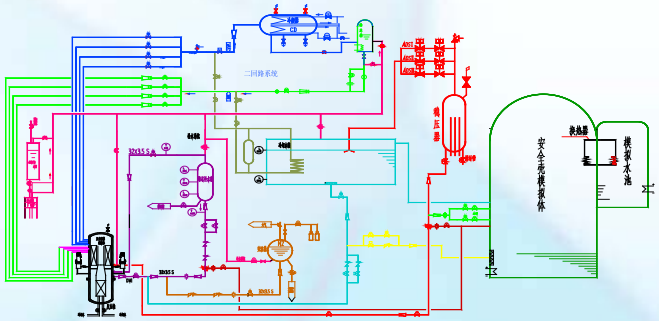
Testing & Verification

Seven test research

- Control rod drive line cold and hot test
- Control rod drive line anti-earthquake test
- Internals vibration test research
- Fuel assembly critical heat flux test research
- Passive emergency core cooling system integration test
- CMT and passive residual heat removal system test research
- Passive containment heat removal testing



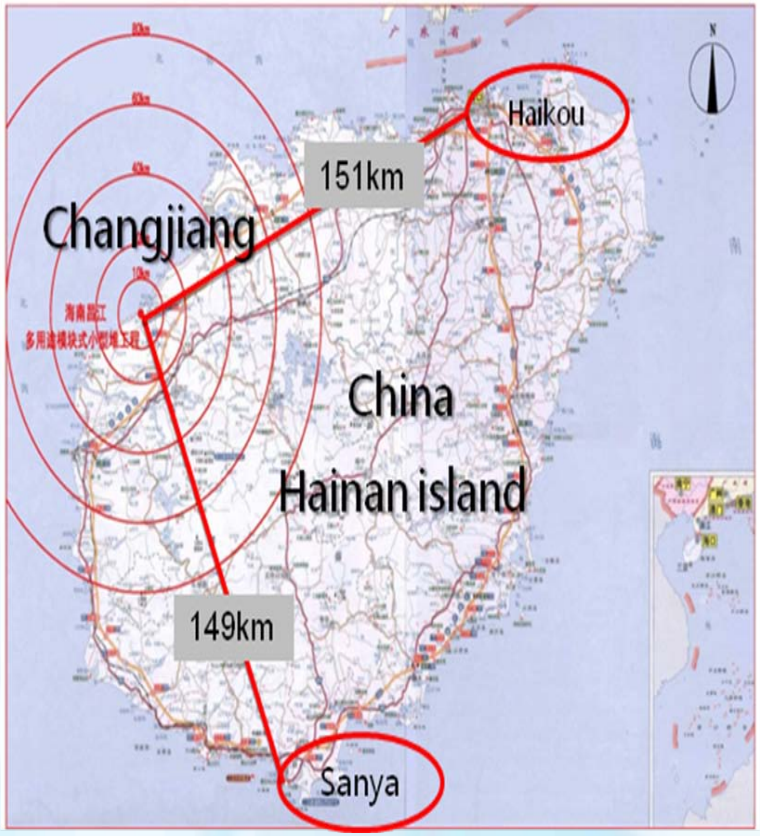
Thermal hydraulic testing hall



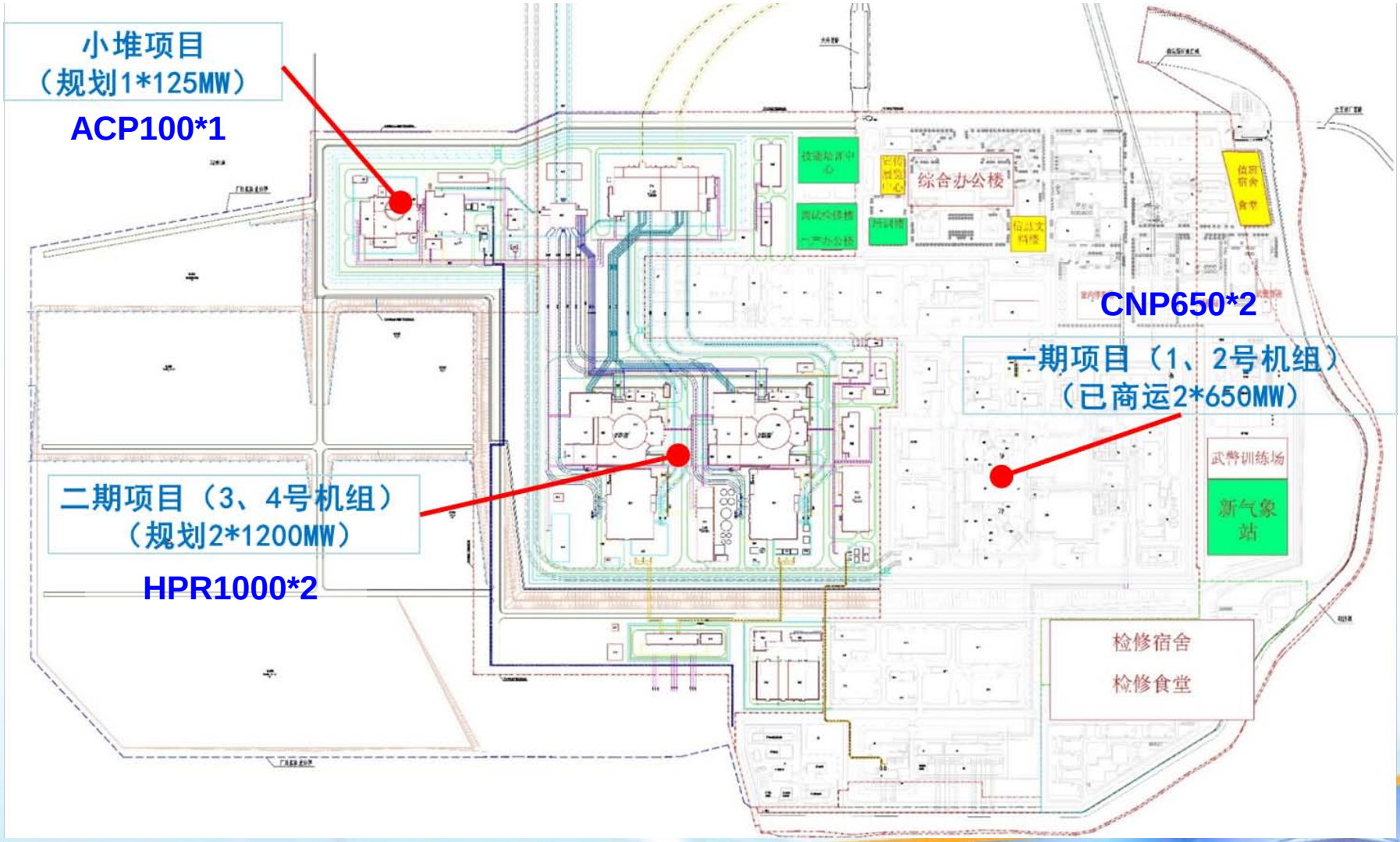
Passive emergency core cooling system

Demonstration project of ACP100

- *Changjiang nuclear power site, Hainan, China, as illustrated in Figure, was chosen to build the first of a kind (FOAK) ACP100 demonstration project.*
- *FCD in July, 2021.*
- *Construction period of FOAK 55 months, target commercial operation in 2026*



Demonstration project of ACP100



Demonstration project of ACP100

- ***Major equipment, such as Reactor Pressure Vessel, Steam generator and Tubine Generator already in manufacturing stage.***

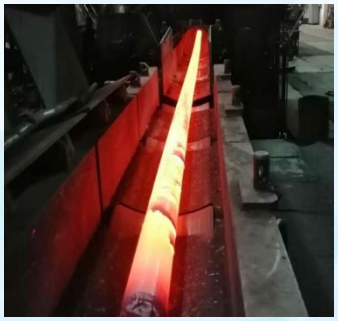
RPV主泵接管锻件

RPV支承段筒体堆焊

RPV容器法兰堆焊

RPV主泵接管待堆焊

主泵试验回路



SG钛管热轧

主泵电机组装

Demonstration project of ACP100

- **Site preparation on 18 July, 2019**

小堆施工现场

Demonstration project of ACP100

- **Site preparation on 31 December, 2019**

Demonstration project of ACP100

- **Site preparation on 30 June, 2020**

Demonstration project of ACP100

- **Site preparation on 26 February, 2021**

Demonstration project of ACP100

- **FCD on 13 July, 2021**

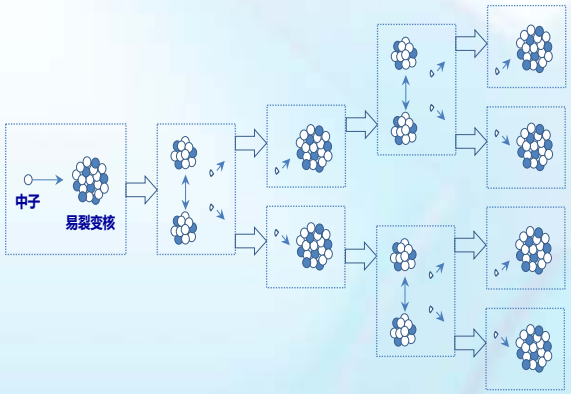
Multiple applications of ACP100

Merit of nuclear energy:

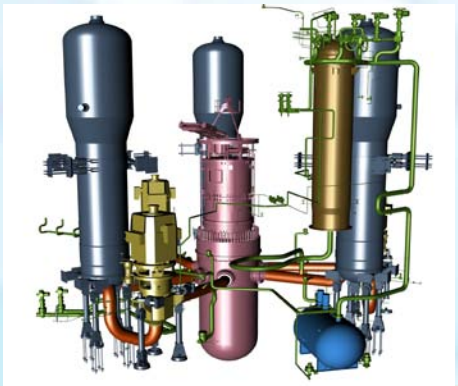
- ***Higher density, lower carbon emission***
- ***Stable opertion, no fluctuation***

1kgU^{235}=2700 Ton Coal

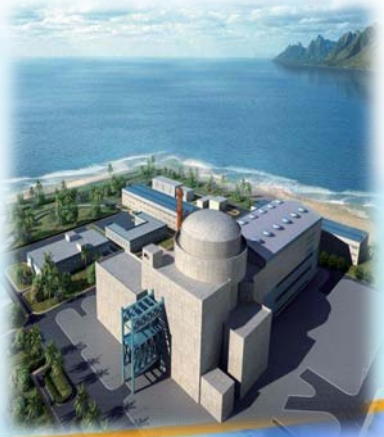
1000MWe NPP de-carbonize 6.60 E7 Ton Coal



自持链式核反应



反应堆



核能发电

Multiple applications of ACP100

- 80% end user of energy，including electricity, heating, transportation
- In year 2019, energy consumption of China (electricity 23.9%， heating 45% (Industry 24%，civil 21%）， transportation 11%)

ENERGY	Electricity	Heating		Transportation	Others
		Industry	Civil		
	23.9%	24%	21%	11%	小

Multiple applications of ACP100

Electricity

- Increasing electricity demand
  - Electricity demand in China from 7.5*10E13 Kwh in 2020 to 1.17*10E14 Kwh in 2050
  - Portion of fossil plant will decrease from 63.2% in 2020 to 20% in 2060
- Several choices for replacement of fossil plant
  - Wind and solar
  - Hydraulic power
  - Nuclear energy can access grid stable as base load energy

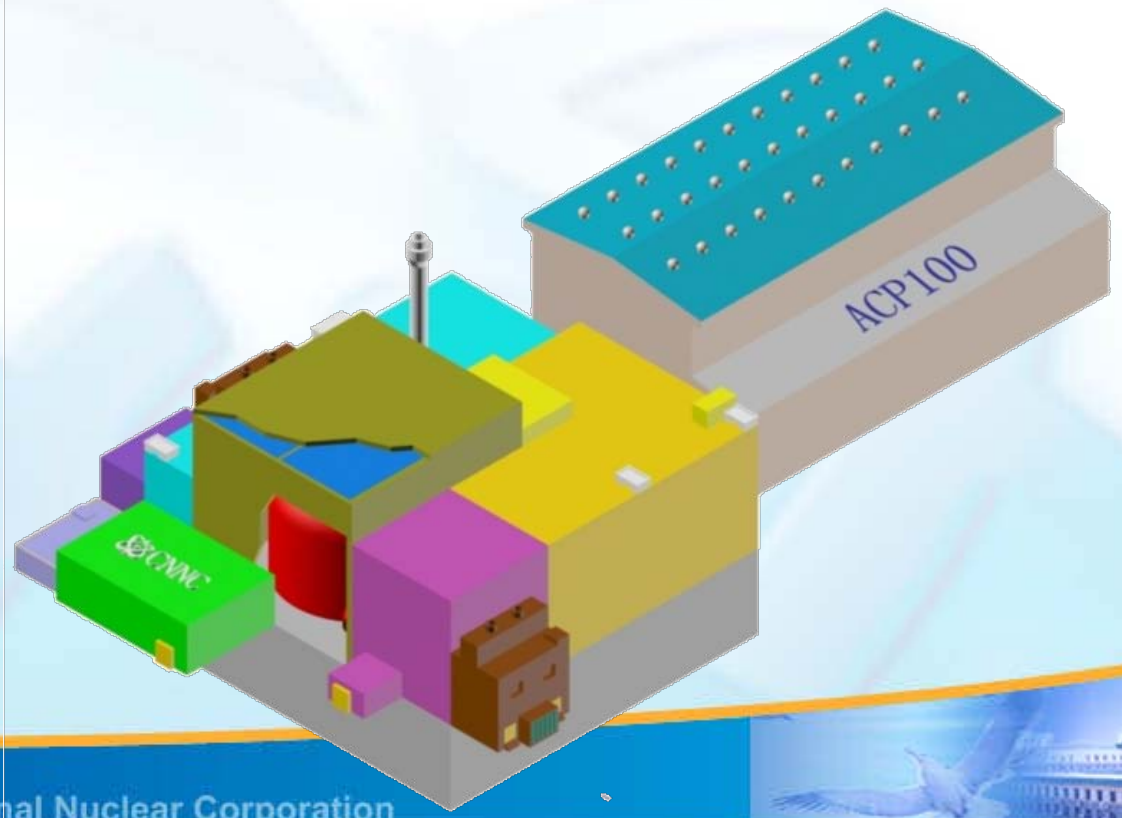
Heating

- 2/3 of heating are used for industry area, 40% of total CO2 emission of the world. Nuclear energy can play key role.

Multiple applications of ACP100

In the fields of Electricity Generation

- Hainan Changjiag Project (under construction):
- Electrical Power 126.5Mwe , Refueling period 24 months. Electrical generation 10^9 Kwh/year , Satisfy for 0.52 million families.

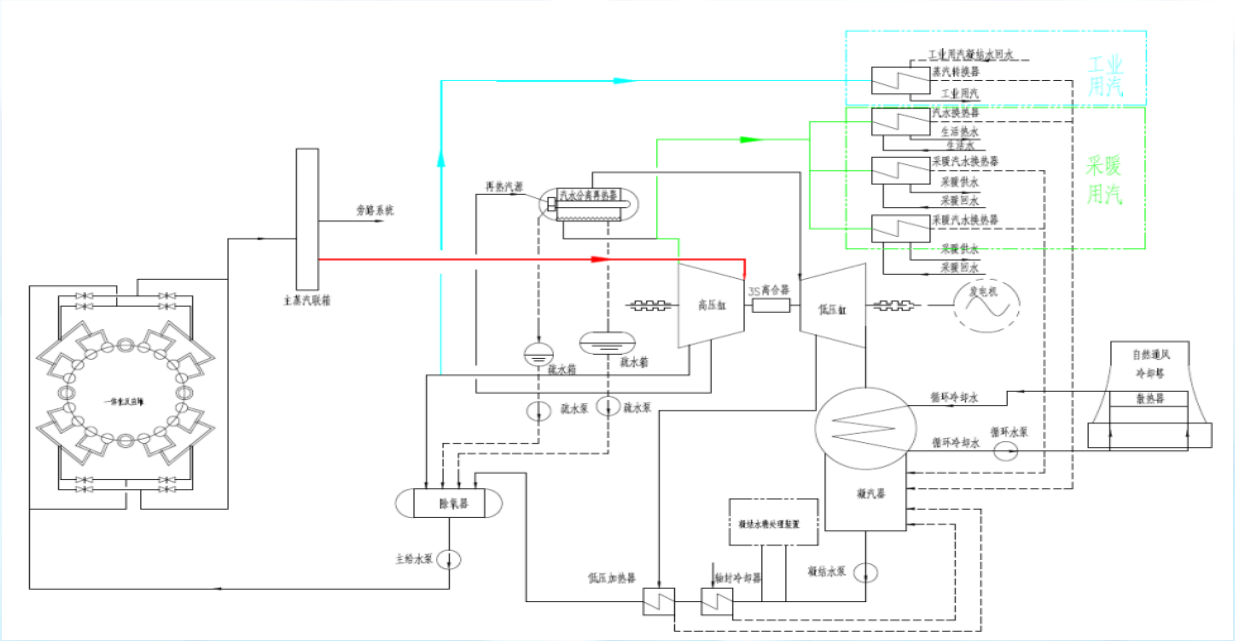


Multiple applications of ACP100

In the fields of District heating & Electricity Generation

Gansu Jingta project (feasibility study)

Thermal generation：6.55 million GJ/year;
Electrical power：80 Mwe;
Electrical generation：0.425 E10^9 kWh/year;



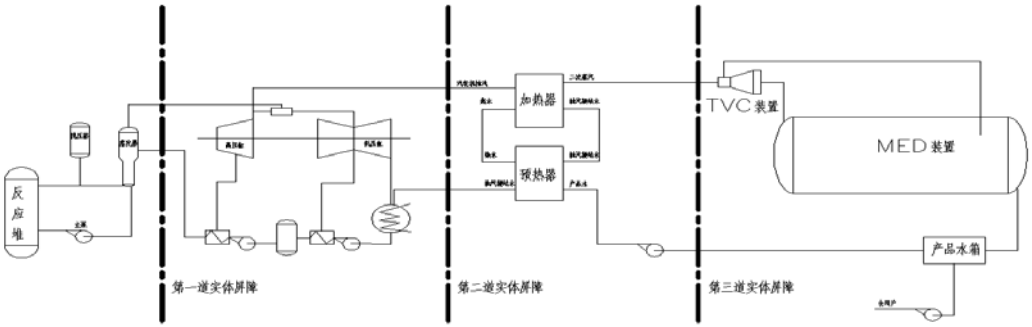
Multiple applications of ACP100

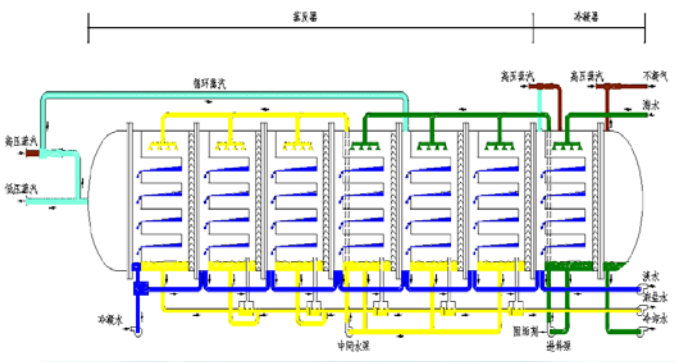
In the fields of Seawater Desalination & Electricity Generation

- Gansu Jingta project (feasibility study)

(Low Temperature Multi-effect Sea Water Desalination Facility) :

- Fresh water generation: 48,000 m3/day
- Electrical generation: 75 MWe





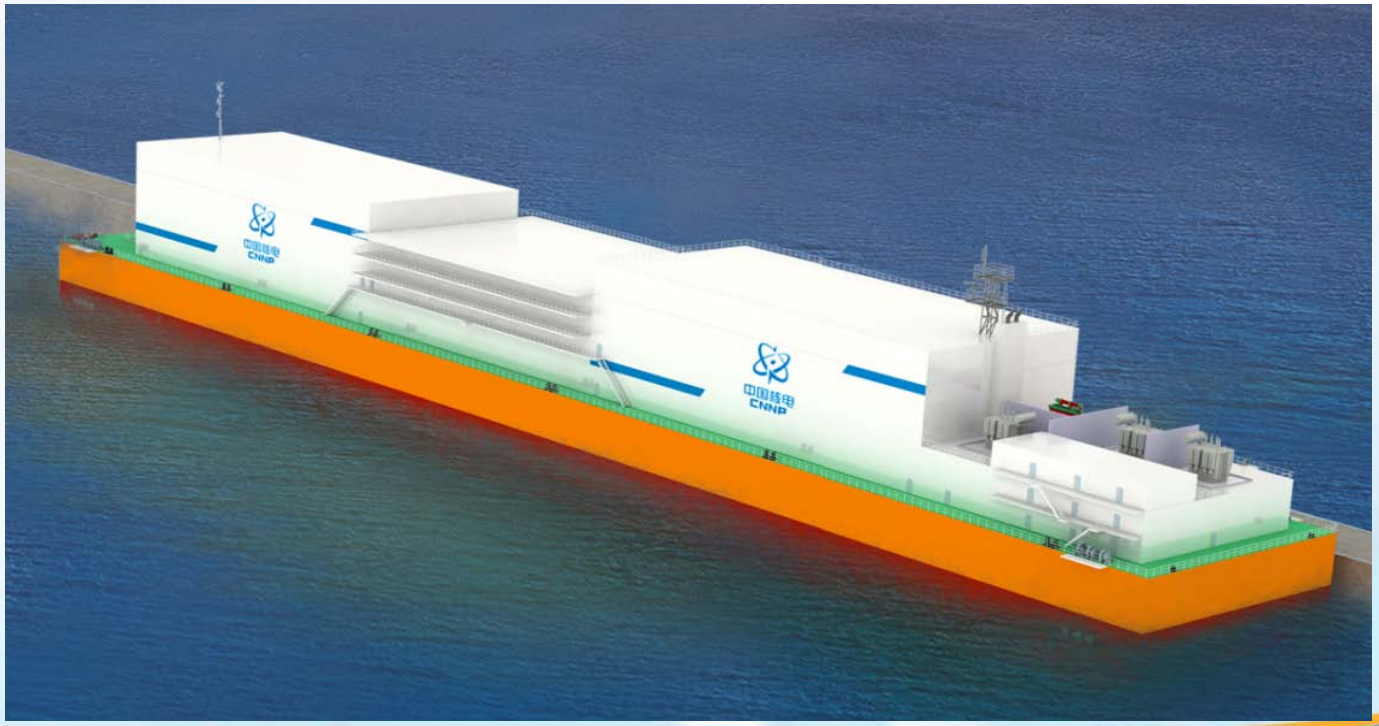
Multiple applications of ACP100

In the fields of Floating Nuclear Power Plant

- Shandong Yantai project (feasibility study)

Two ACP100 reactor on the floating platform

Electrical generation：250 MWe



Thanks and Questions