Progress of Advanced and Small Modular Reactor

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01 General Introduction

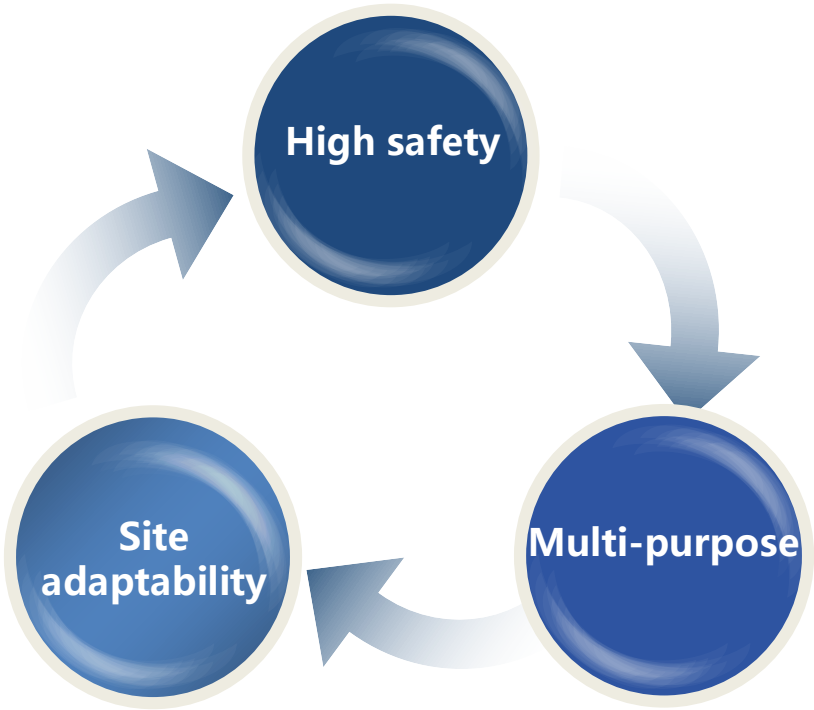
1.General Introduction

- The International Atomic Energy Agency (IAEA) defines a "small nuclear reactor" as a kind of nuclear reactor power plant with a electric power of less than 300MW. On this basis, the concept of modularization was later added, which is, **Small Modular Reactor.**

  - The reactor and reactor coolant system are integrated into reactor modules, which **can be manufactured, transported as a whole, assembled quickly, and scale economy can be achieved through modules in volume production.**

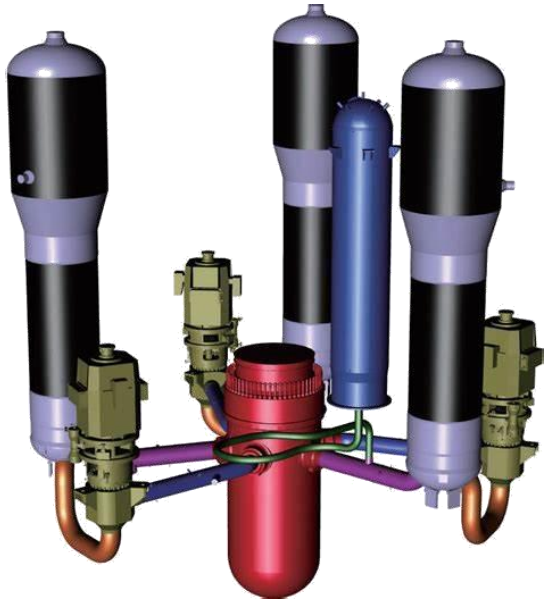
- **Comparing to large reactors, small reactors have their own characteristics and advantages:**

  - **Small power scale, simple system and low initial investment in construction**
  - **High safety performance, can be built around populated areas such as large cities.**
  - **Flexible operation, strong ability to adapt to load follow.**
  - **Modular, with short construction time**
  - **Site condition are simplified with flexible site selection**

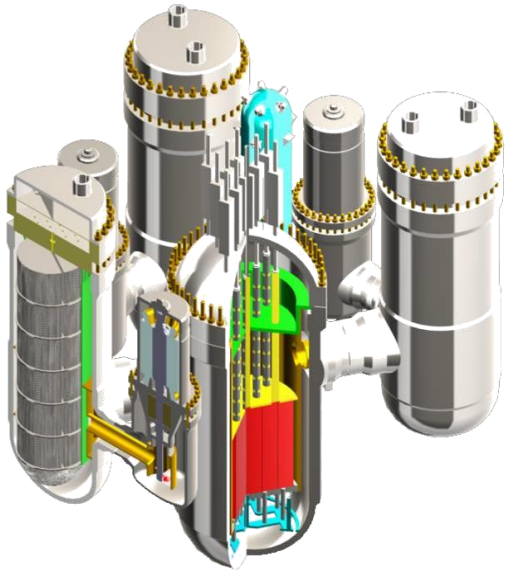


□ ACP100 “Linglong-1” is an innovative PWR based on existing PWR technology, adopting “passive” safety system and “integrated” reactor design.

more compact → more advanced → safer



Conventional loop reactor



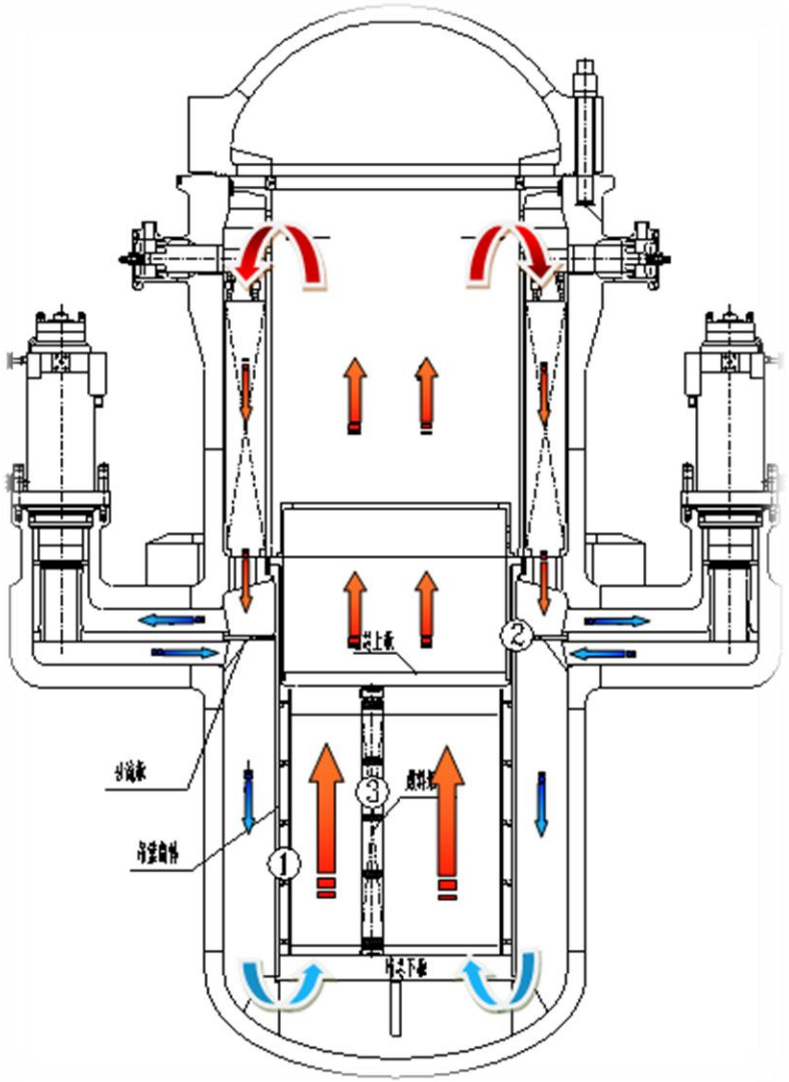
Compact improved reactor

Innovatory Reactor

1.General Introduction

□ General Parameters

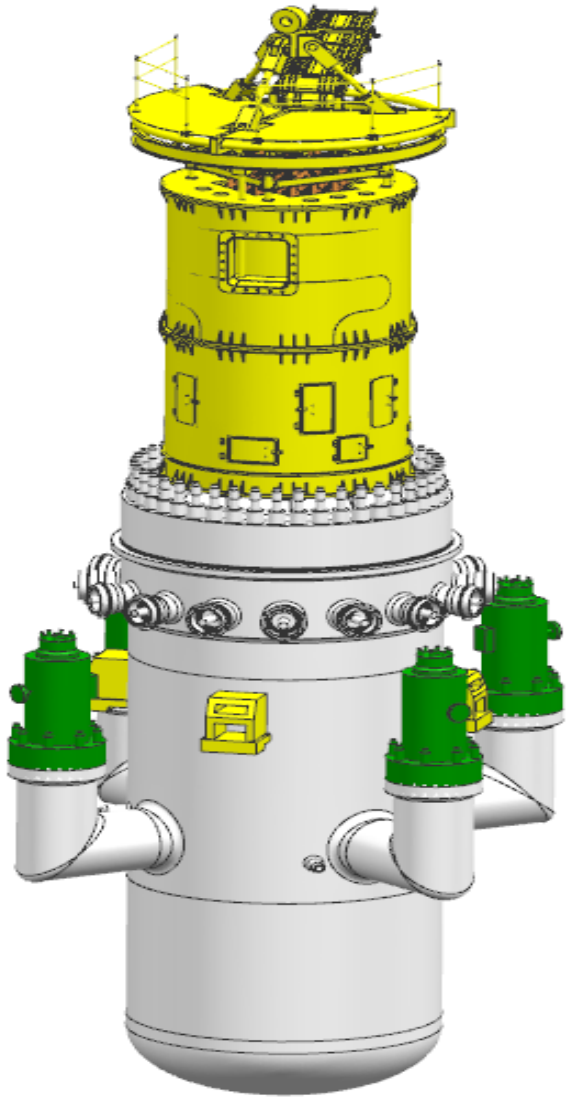
Parameters	ACP100
Reactor Thermal power，MWt	385
Electrical power，MWe	126.5
Design life,year	60
Refueling period,year	2
SSE Level-2 ground seismic peak acceleration, g	0.3
Core Damage Frequency (CDF)	＜1E-6 Per reactor year
Large Radioactive Release Frequency (LRF)	＜1E-7 Per reactor year
Fuel assembly type	CF3S
Fuel assembly number	57
Fuel active section height，m	2.15
Coolant average temperature，℃	303.0



□ Technical Features

➢ **Highly Modular Reactor**

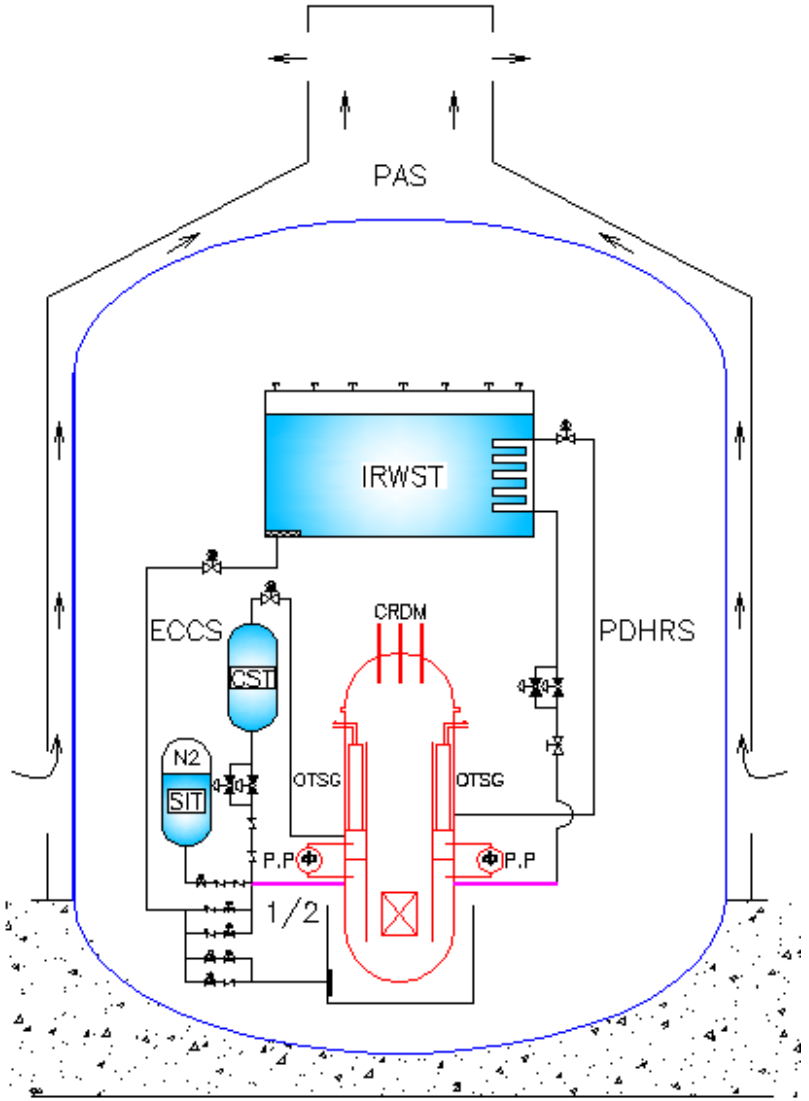
- ✓ **SG built-inside RPV**
- ✓ **Pump shell welded on the RPV cylinder, factory is responsible for manufacturing and delivery , as well as RPV**
- ✓ **Integrated reactor head package**
- ✓ **Integration layout could reduce accident possibility from happening and mitigate consequences if happens, slow down accident progress, and win more response time**



Technical Features

- **Inherent safety and passive safety**

- ✓ Multiple inherent safety characteristics
- ✓ Eliminate multiple DBA through design
- ✓ Completely passive safety system
- ✓ The core damage frequency is less than 10^{-6}, with high safety features
- ✓ Could be no human intervention for a long time after an accident

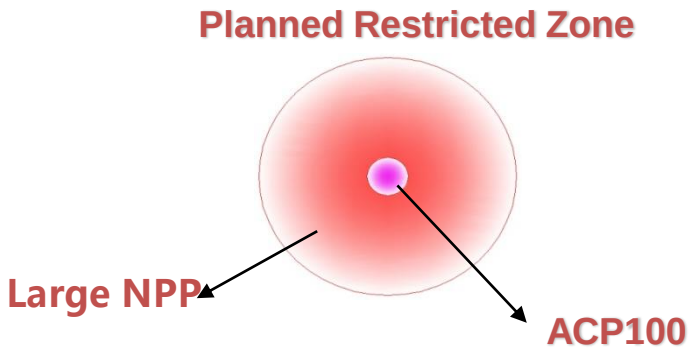


ACP100 safety system layout diagram

□ Technical Features

➢ Off-site emergency can be cancelled technically

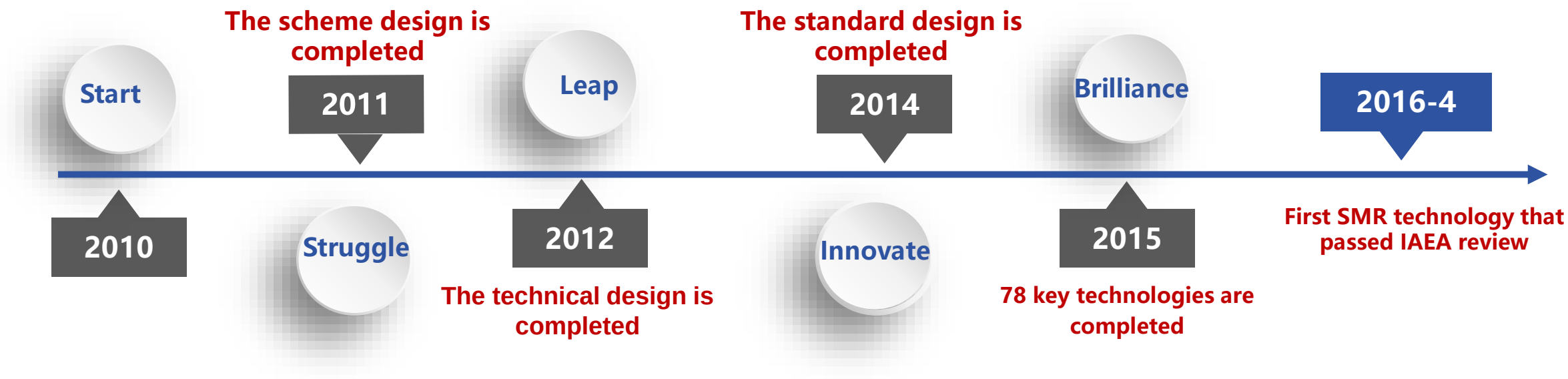
✓ SMR could combine 3 zones into 1, with its 500m radius, the site boundary, so there’ s no need of off-site emergency. (Which could make it) Closer to the residential areas without affecting the nearby economic development.



02 The R&D of ACP100

Roadmap of ACP100 development

- ACP100 "Linglong-1" is a multi-purposed small modular reactor that independently designed by China National Nuclear Corporation(CNNC) from 2010.



Experimental Verification

- Passive emergency core cooling system integration test
- Cold/hot and seismic test of CRDM
- Reactor Hydraulic simulation test
- Experimental study on vibration of RPV Internals
- Passive containment heat removal system experimental study
- Fuel Assembly Critical Heat Flux experimental study

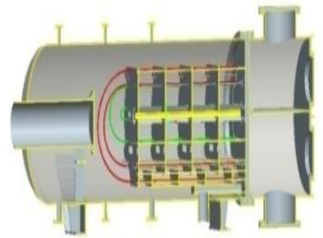




Research and manufacture of key equipment

- Completion of 12 prototype equipments.
-
- Overcome the manufacturing technical difficulties of the main equipments and all domestic supply are realized.

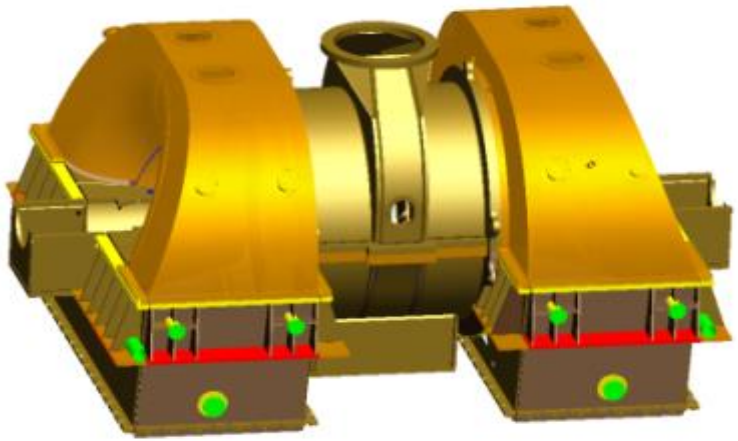
  - Reactor Pressure Vessel
  - High performance Steam Generator
  - Shielded Main Pump
  - RPV Internals
  - Control Rod Drive Mechanism
  - Pressurizer



☐ Research and manufacture of key equipment

- The Fuel Assemble adopts CF3S （shortened CF3）with independent Intellectual Property rights of CNNC

- Several domestic manufacturers of 100MWe class small nuclear power turbine-generators are optional



Third Party Verification

- In order to ensure the safety of ACP100, the National Nuclear and Radiation Safety Center is fully involved in the design and test process.

- A total of 25 safety studies and independent calculation verification have been carried out independently in 5 years to meet the requirements of the latest nuclear safety regulations in China.

Third Party Verification

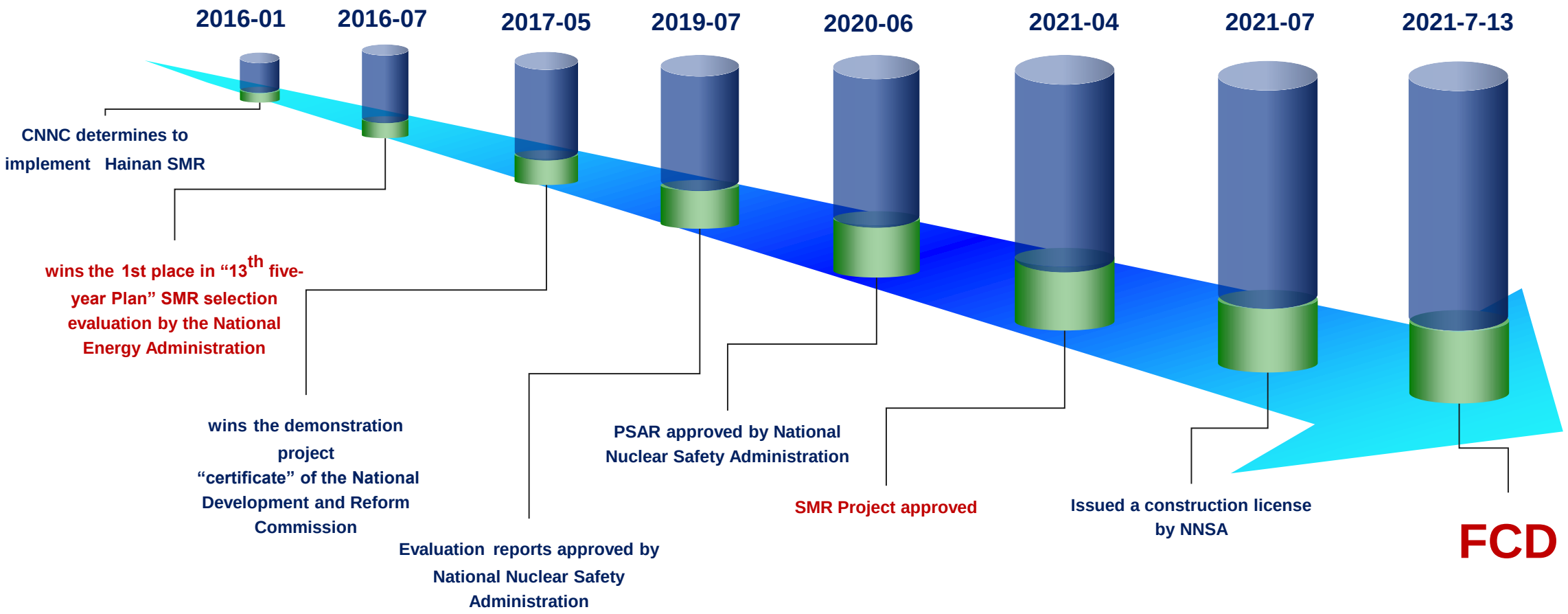
- On April 22, 2016, IAEA provided the final report of the ACP100 generic reactor safety review to the CNNC at its headquarters in Vienna.
- ACP100 became the world’ s first small reactor technology to accomplished the GRSR.

◻ Third Party Verification

……IAEA experts believe that the design of ACP100 is an innovative small PWR design, which adopts "inherent safety and passive safety" design, which is expected to deal with extreme environmental conditions and multiple faults, and ensure the actual elimination of early or large-scale radioactive release.

03 The Construction of ACP100

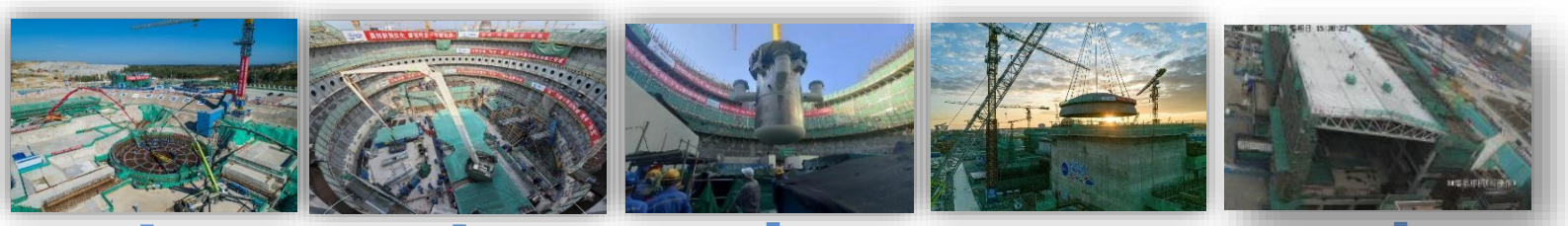
Roadmap of ACP100 demostration project (Hainan SMR)



General Status

□ Schedules

SMR project officially started on July 13th 2021, with a total of 27 milestones, so far 11 of which have been achieved. The project has entered the installation stage, and all work is progressing smoothly, safety and quality are under full control, and the project progress is in line with expectations.



1. Nuclear Island FCD — 2021.07.13
2. The internal structure construction of the reactor building was completed — 2023.03.08
3. The integrated pressure vessel is lifted in place — 2023.08.10
4. The Containment Vessle head is lifted in place — 2023.11.03
5. Steam turbine installation starts — 2024.03.12

Temporary acceptance target: 2025.12.31 (FCD+53.5)

Milestones

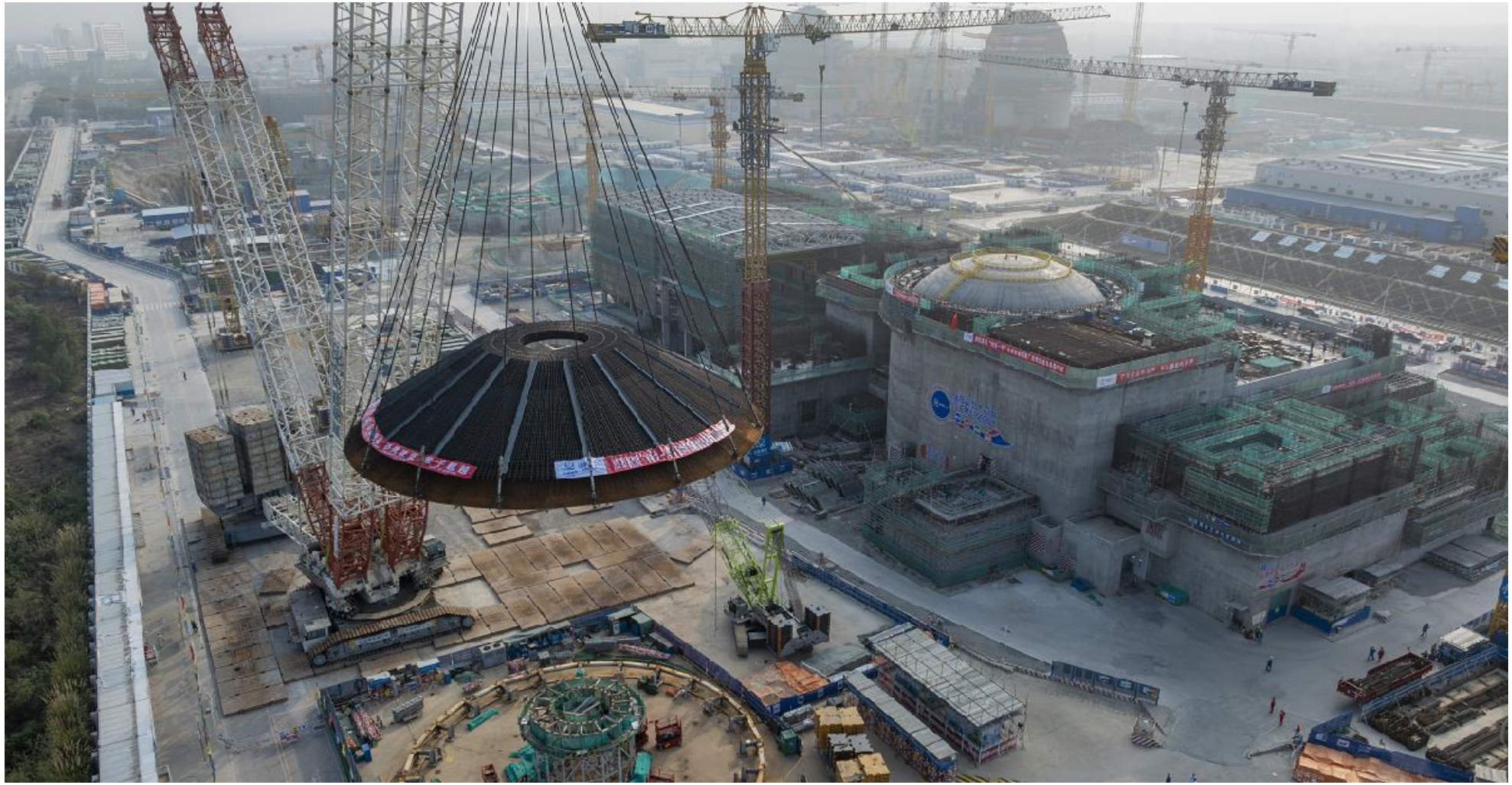
- **July 13th 2021, FCD on-site scenes**

□ Milestones

- **August 10th 2023, the core equipment(RPV and OTSG) was hoisted into position**

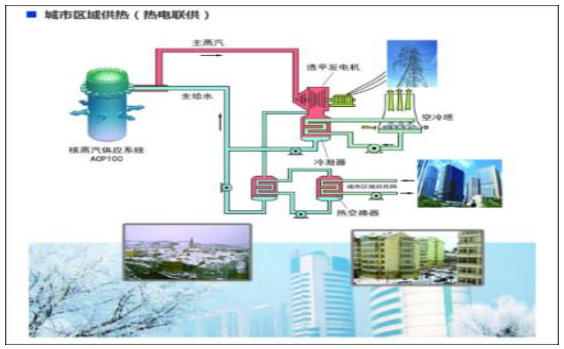
◻ Milestones

- **February 6th, 2024, the outer dome was hoisted into position**

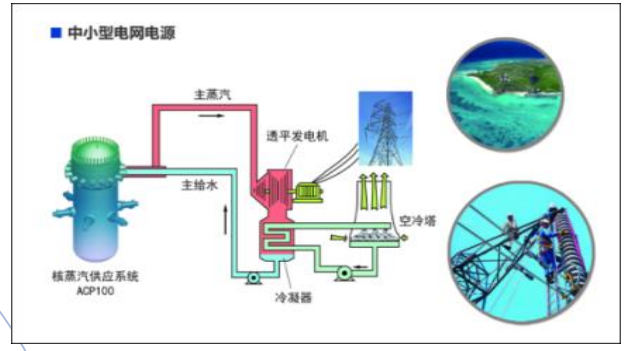


04 Multi-purpose Applications for SMR

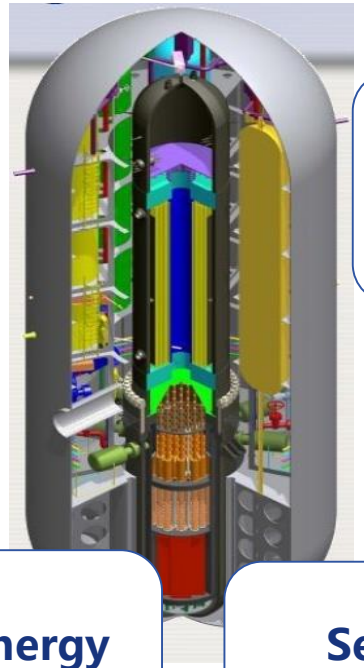
4.Multi-purpose Applications for SMR



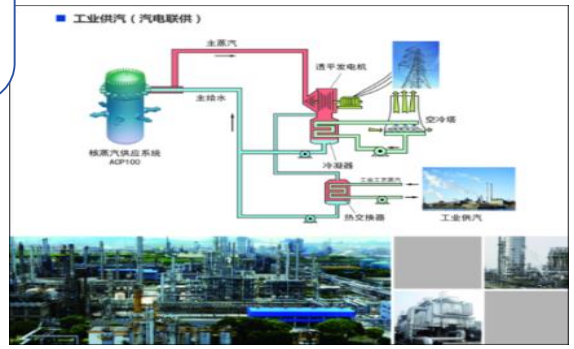
Small, medium and regional power grid

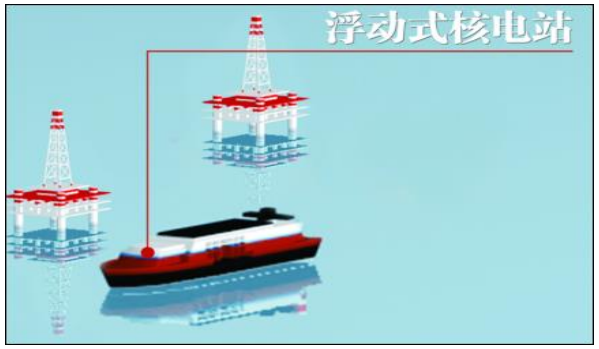


District heating for replaceing coal



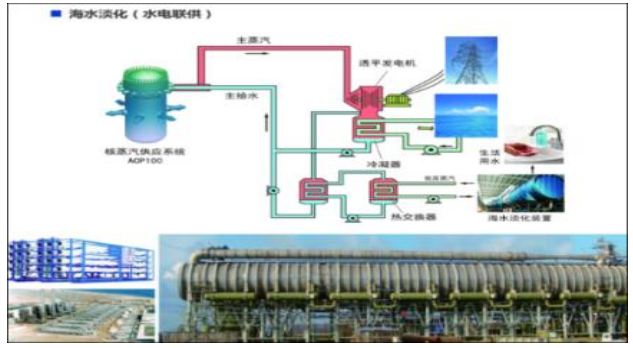
Industrial steam and cogeneration





Floating energy application

Seawater desalination



4.Multi-purpose Applications for SMR

◻ Replacement of Old Small-scale Thermal Power Plant

- Small-scale thermal power plants consume a lot of energy and pollute the environment

- The elimination of old small thermal power plants is an important measure to protect the environment and promote the transformation of energy structure.

- Multi-purpose SMRs can be well used as alternative energy sources due to their high construction economy and device adaptability.

4.Multi-purpose Applications for SMR

◻ Small, Medium and Regional Power Grid

- **Small and medium units are absolutely dominant in the existing operating power stations, and 93% of the global installed capacity is below 500 MWe**

- **Most developing countries have small and medium power grids, which have gradually become the main force for the growth of the global nuclear power market.**

- **The multi-purpose SMR is easy to construct and highly economical, and the scale can be configured according to regional power demand.**

4.Multi-purpose Applications for SMR

◻ District and Process Heating/Cooling

- **Thermal power accounts for the largest proportion of final energy consumption, 2/3 of which is industrial heating. The resulting CO_2 emissions account for 40% of the total global emissions, which is the key to carbon neutrality.**

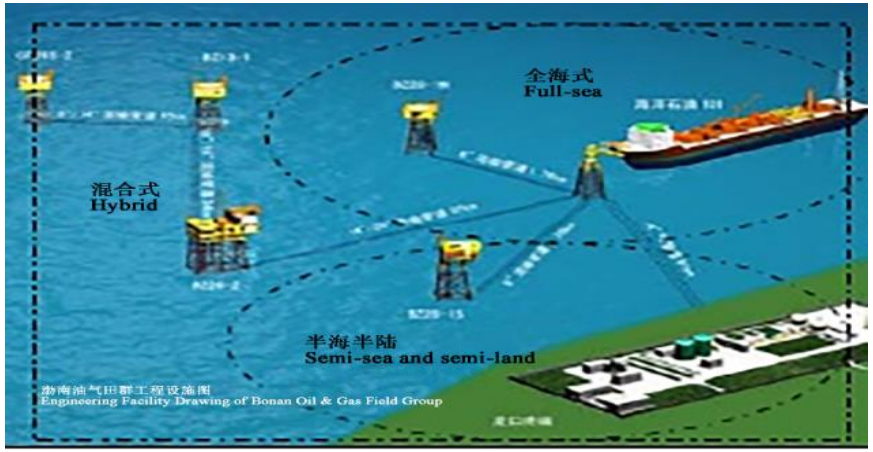
- **There is also a demand for heating in various industrial fields, such as desalination, hydrogen production, and steelmaking.**

- **SMRs can provide heat sources close to the users.**

4.Multi-purpose Applications for SMR

◻ Energy Supply Station on the Ocean

- The ocean holds abundant resources, and reliable energy supply is required for its development。
- Floating nuclear power plants equipped with SMRs can provide safe and reliable energies for marine resource development, island and reef construction, and offshore replenishment。



4.Multi-purpose Applications for SMR

◻ Seawater Desalination

- **It is estimated that by 2025, nearly one third of the world's population (2.3 billion) will have water shortages, affecting more than 40 countries and territories.**

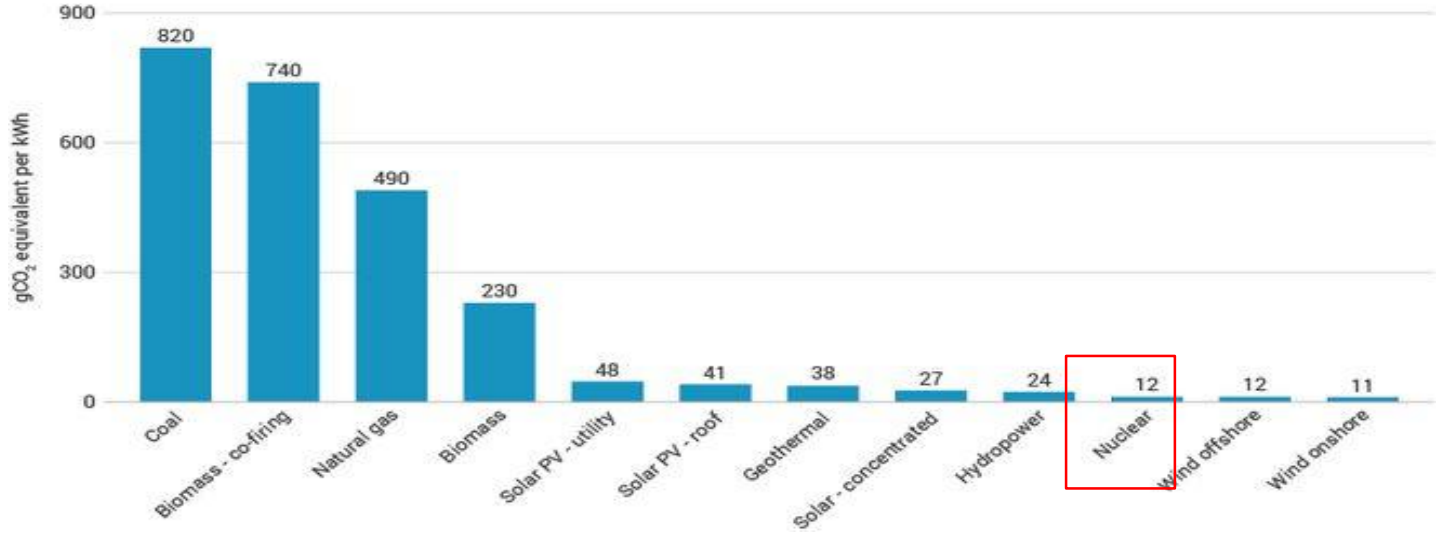
- **Advanced multi-purpose SMRs can provide a stable water source that is not affected by climate, effectively increasing the total amount of freshwater resources in coastal areas.**

05 The Future Development Prospects of SMR

5.The Future Development Prospects of SMR

◻ Carbon emissions and carbon tax

- According to the data of the World Nuclear Energy Association, the carbon emissions per 1 kWh of electricity produced in the whole life cycle of **nuclear power is 12g**, which is comparable to wind power.
- In another statistical context, the **IAEA believes** that nuclear energy emissions per unit of electricity is the lowest, **between 5.1g and 6.4g**, far lower than Solar and Hydropower.

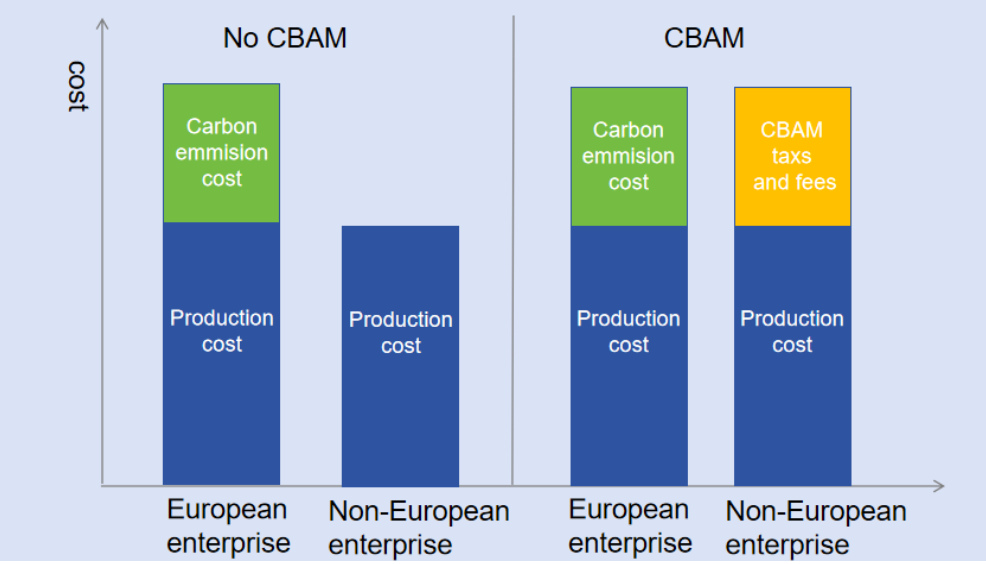


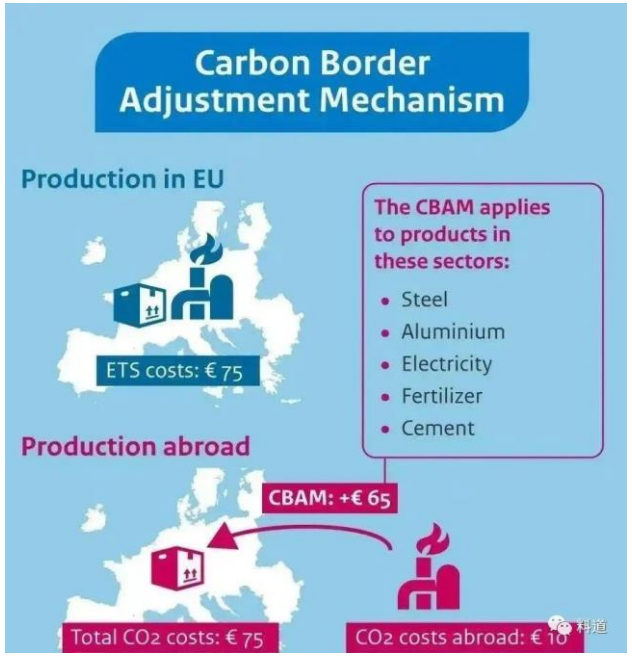
Carbon emissions per unit of electricity for different technology routes
（source：World Nuclear Association）

5.The Future Development Prospects of SMR

◻ Carbon emissions and carbon tax

- In order to avoid carbon leakage and mitigate the risk of declining competitiveness of EU enterprises, the EU passed a law announcing that **the carbon border adjustment mechanism (CBAM)** will be officially implemented on January 1, 2026.
- The scope of carbon emissions accounting includes not only direct emissions from imported products, **but also indirect emissions from purchased electricity.**
- In terms of the electricity purchased during production, **the indirect emissions costs from nuclear power are negligible** compared to coal power plant.





5.The Future Development Prospects of SMR

◻ The economy of ACP100 SMR

- **The total cost is 800,000 million RMB for a ACP100 plant with 2 reactors together.**

Plant type	electricity price(RMB/kWh)
Large NPP	0.43
coal plant	0.38-0.45
Wind power plant	0.25-0.3
hydropower plant	0.18-0.36
Solar power plant	0.25-0.3
ACP100	0.5~0.6

5.The Future Development Prospects of SMR

◻ The economy of ACP100 SMR

- **Compared with large NPP, the total construction and operation cost of ACP100 is less.**
- **Compared with new energy, nuclear power generation of ACP100 is stable and can provide capacity support for the power system.**
- **Acp100 nuclear power also has the characteristics of high energy density, large single power, high land utilization, not affected by seasons and climate, and stable power generation costs, which also provides a guarantee for energy security.**
- **Considering the total construction investment, stability, carbon tax and other factors, the ACP100 nuclear power has advantages in its overall performance.**

06

Conclusion

6.Conclusion

- ACP100 is an innovative PWR based on existing PWR technology, adopting "passive" safety system and "integrated" reactor design.

- ACP100 technology has been successfully applied in Changjiang Demonstration project.

- Considering the total construction investment, stability, carbon tax and other factors, the ACP100 small reactor has a certain competitive advantage, and has a large space for development.

Thank You!