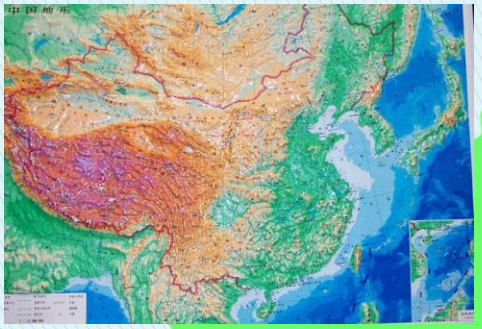
The Development of Multi-Purpose Modular Reactors with Improved Safety in China

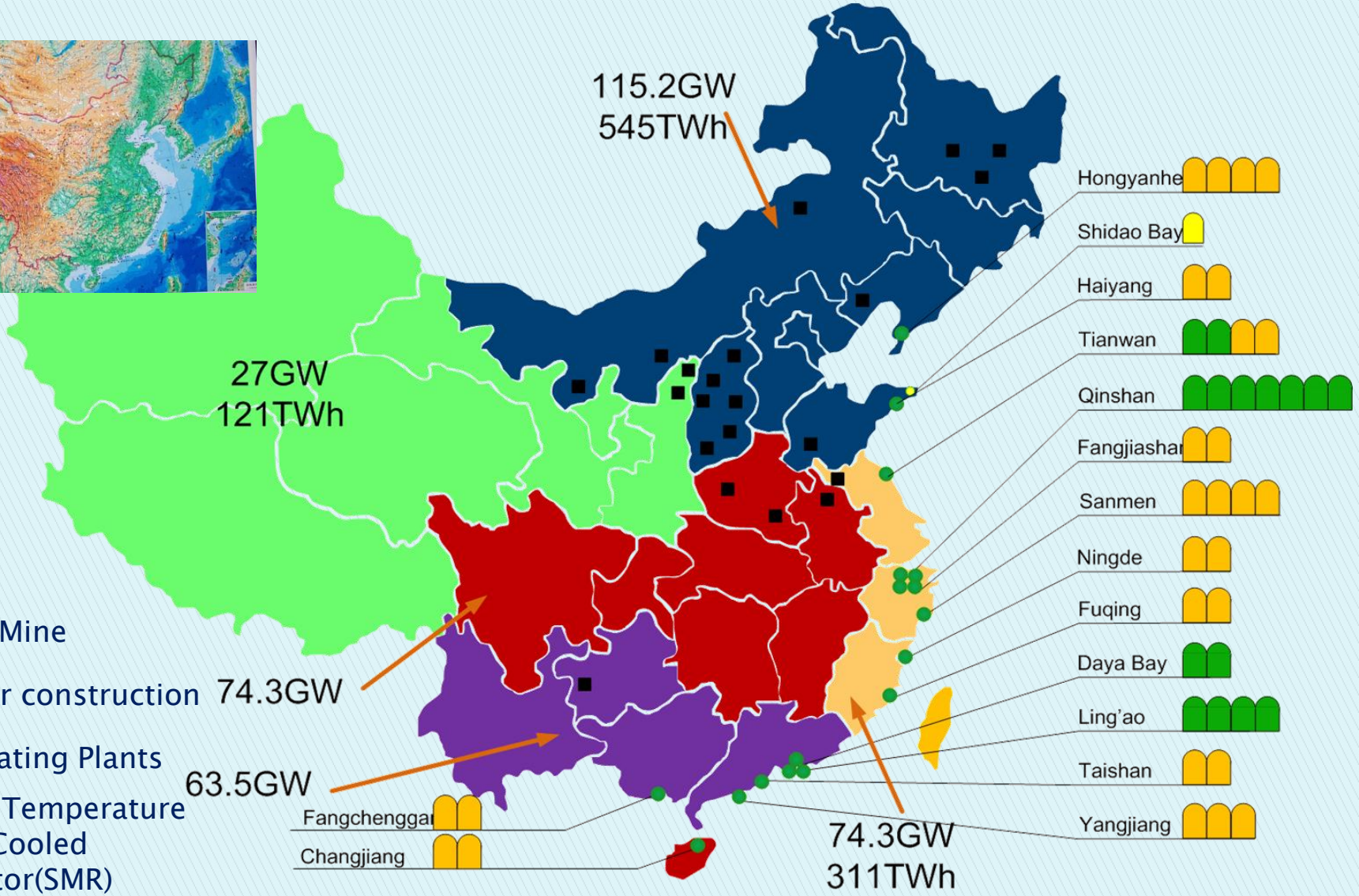
Shan Sun*, Lihong Zhang†

*Huaneng Shandong Shidao Bay Nuclear Power Company

† Institution of Nuclear Energy Technology, Tsinghua University

Overview





- Coal Mine
- Under construction
- Operating Plants
- High Temperature Gas Cooled Reactor(SMR)

Coal fire plant provides more than 80% of electricity generated in China

Coal-Primary Heating Source

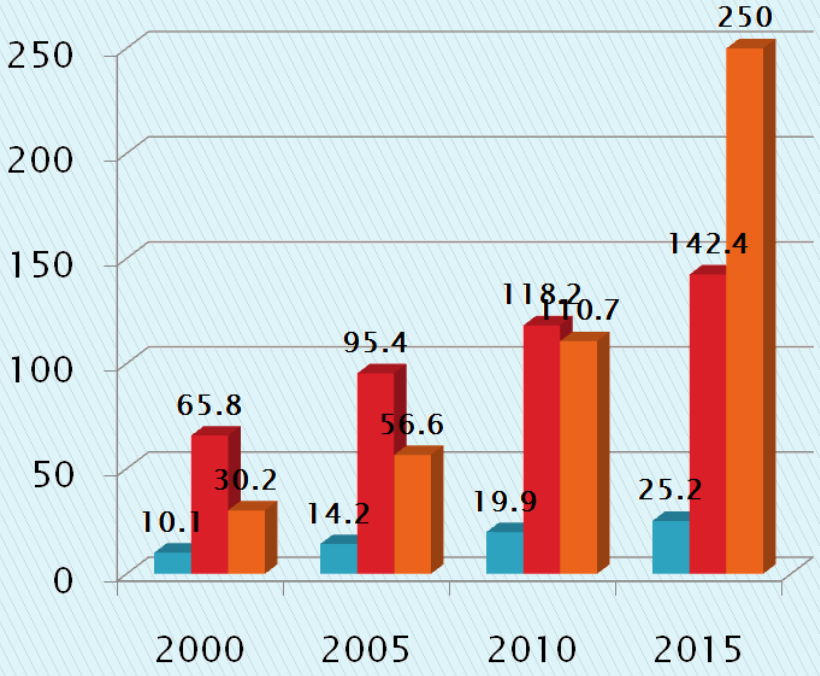
- Multi-billion tons consumed for heating. (10% of coal consumption)
- Mostly relies on distributed boiler and small(<10Mwt) coal fire plant
- Ongoing heat supply network restructure

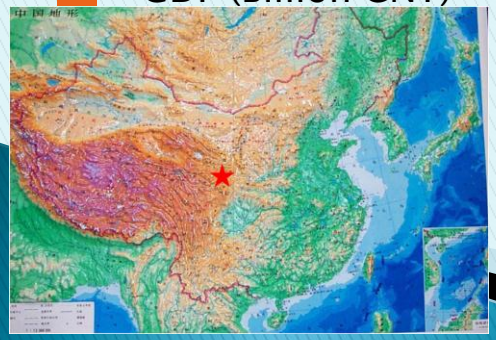
Urge Need from Industry

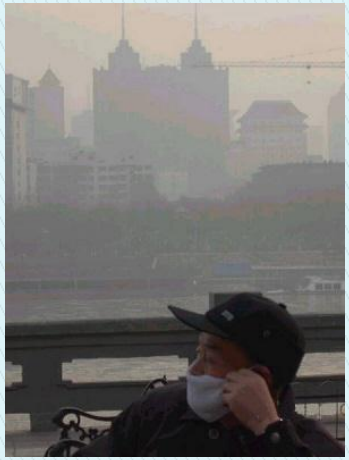
- Low efficiency small plants are built to provide steam for individual factory
- Economically challenged with the rising cost of coal

Lanzhou- a typical city in inland China

Fast growing but in dire need for CLEAN ENERGY

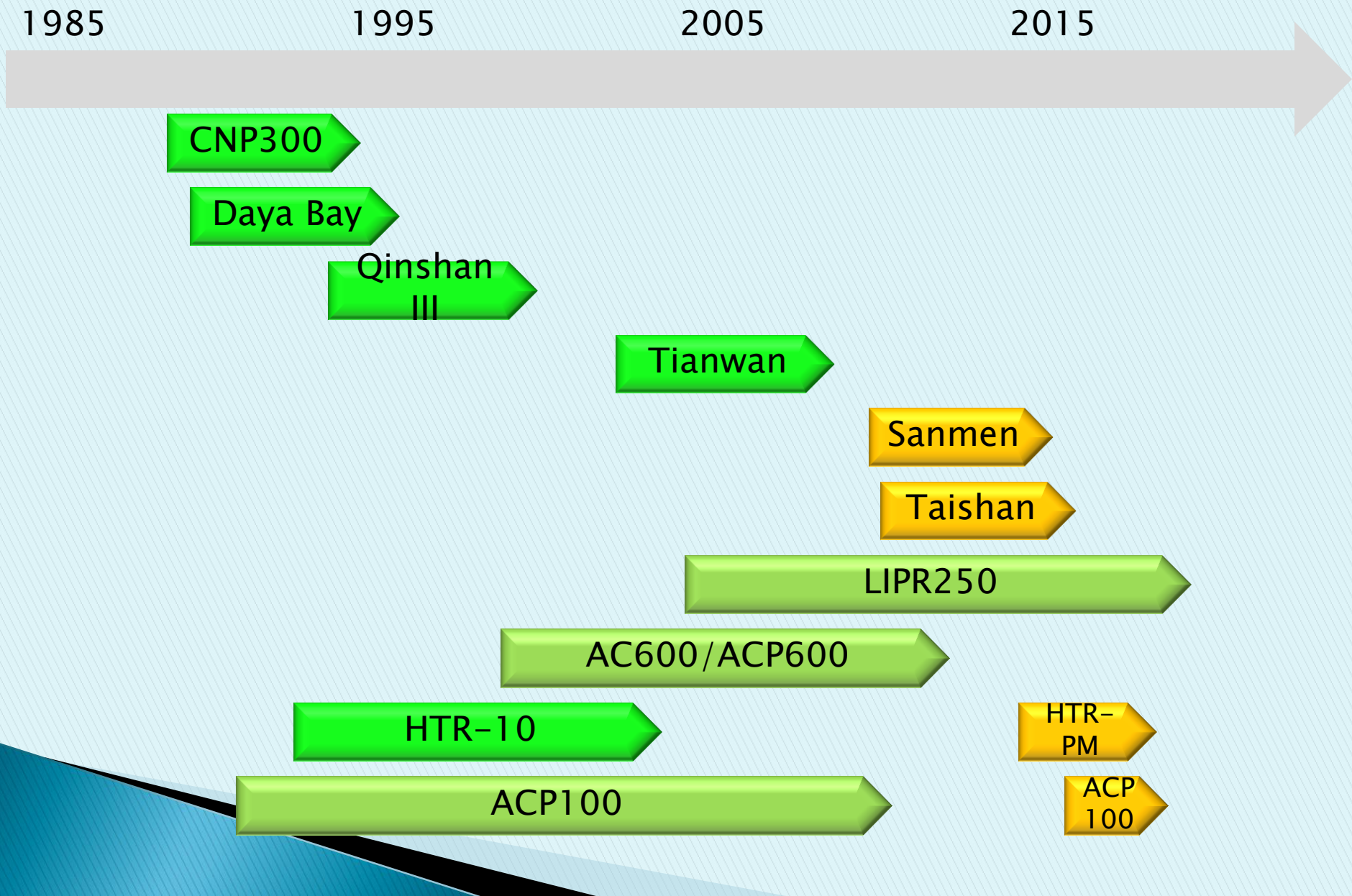






I could really use something that is……

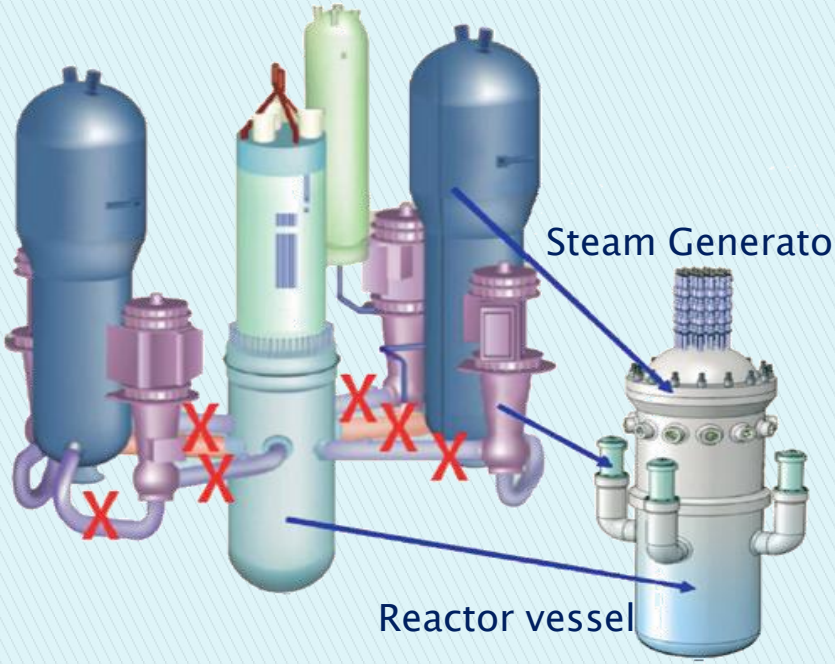
Efforts on commercial reactors



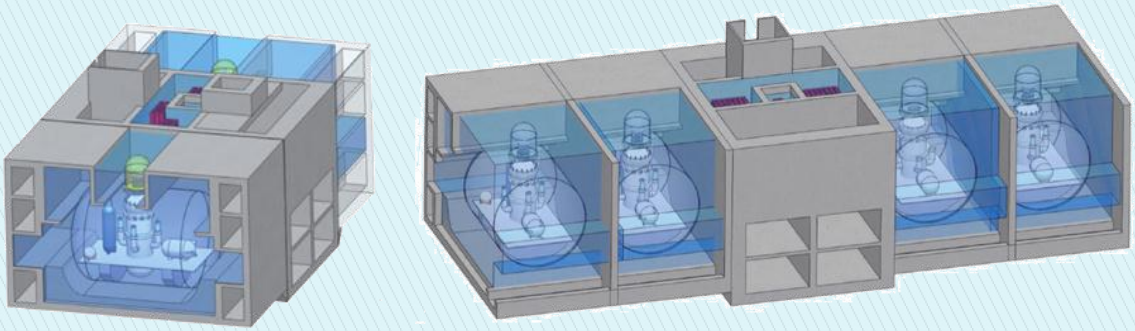
ACP100- a generation III approach

ACP100-a Generation III Approach

ACP100

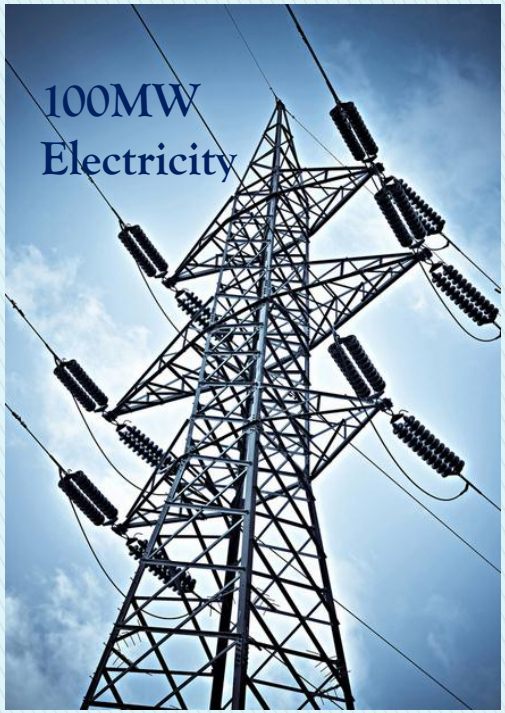


Integral simplification of generation III nuclear plant

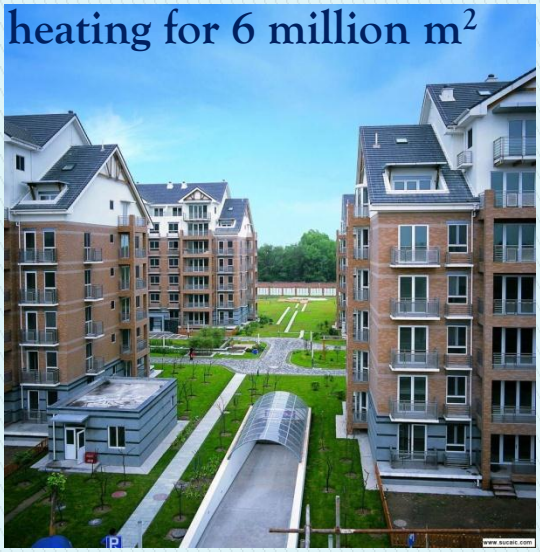


Modular design configurable with 1~8 units

Multiple-purpose



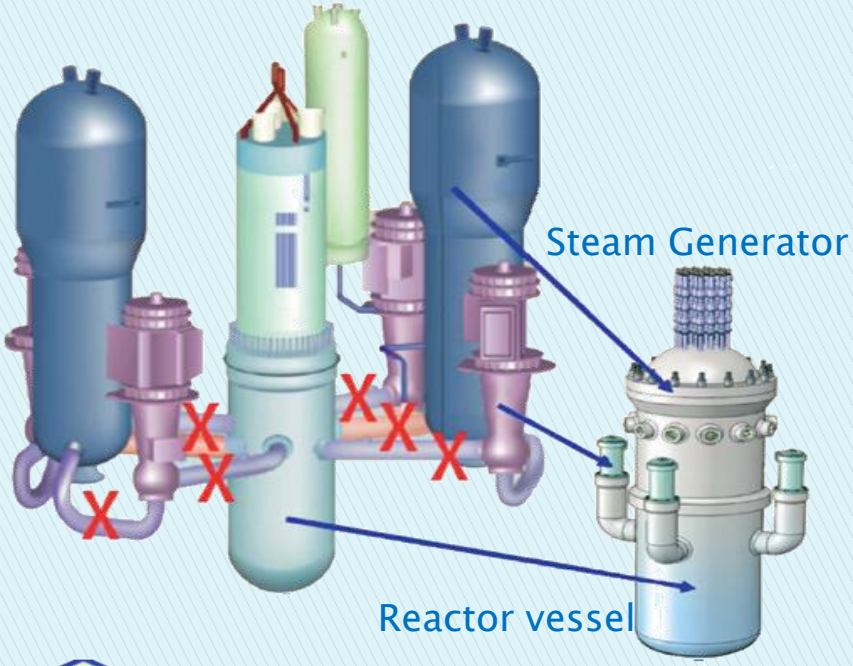
Each module is capable of providing…



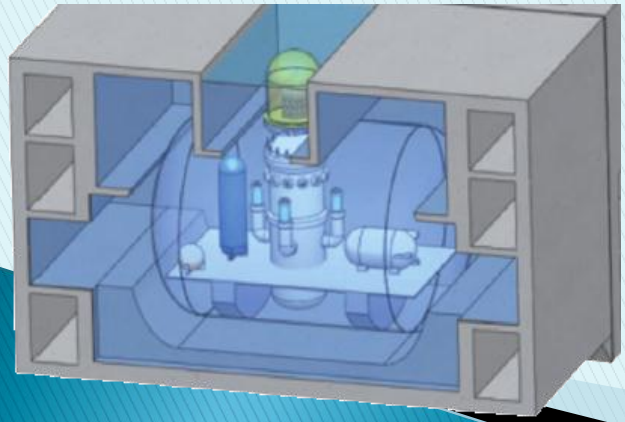
Construction is expected to start by end of 2012…

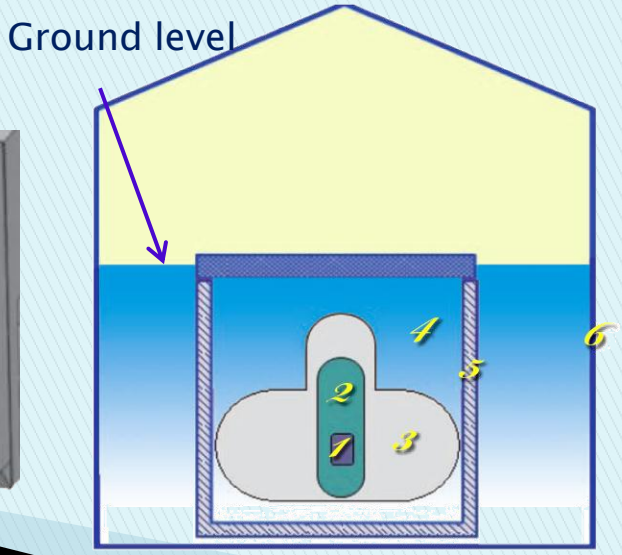
Enhanced Safety

- Integrated design eliminate line break LOCA



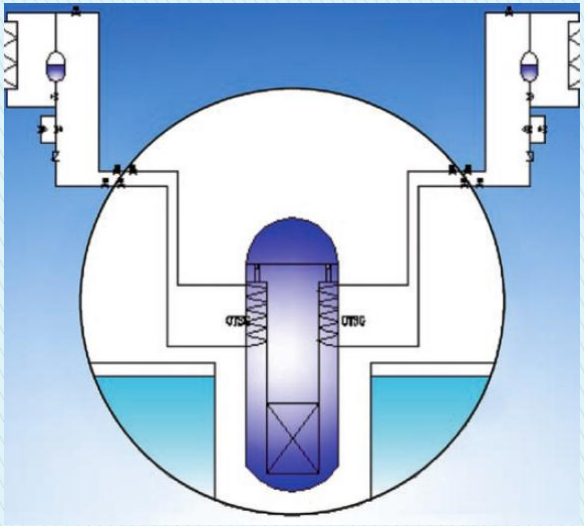
- Multiple safety boundaries
  Core damage frequency<10^{-6}
  Large release frequency <10^{-7}



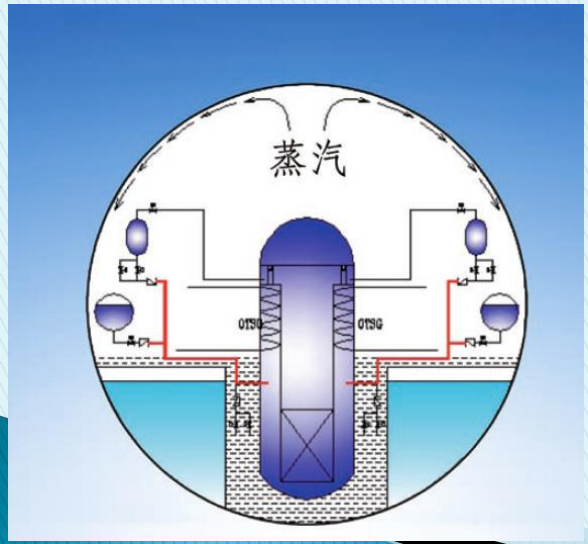


1	Fuel
2	Reactor vessel
3	Steel shell
4	Cooling water
5	Cooling pool
6	Containment

Enhanced Safety



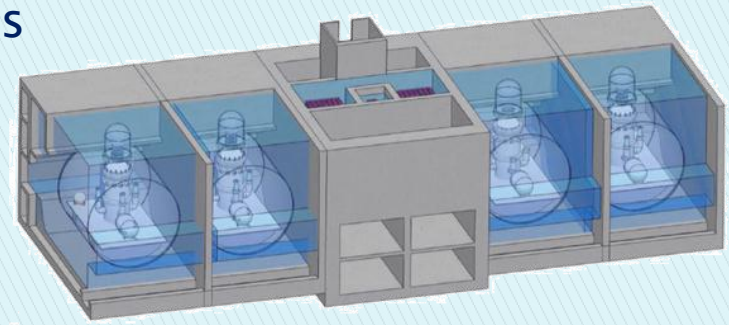
- Forced natural circulation between reactor core and steam generator
- Emergency heat exchanger submerged in the cooling pool
- Passive decay heat removal system provides cooling for 3 days without operator intervention or 14 days with water supply from cooling pool by gravity



- Core cooling using natural circulation between steel shell and reactor core
- Passive core cooling provides cooling for 3 days without operator intervention or 14 days with water supply from cooling pool by gravity

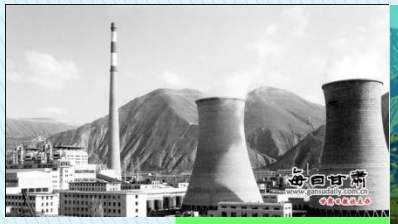
Economics

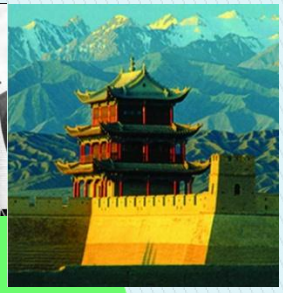
- Flexible configuration with 1~8 modules
- 30 months construction time
- Smaller construction area
- Smaller emergency off-site area
- Easily transportable
- 24 months fuel cycle or longer
- Designed lifetime for 60 years
- Availability >90%



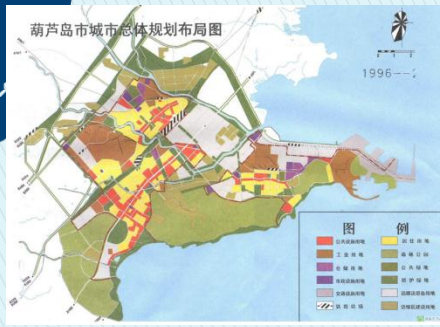
ACP100 is estimated to be competitive against large reactors if more than 4 modules are built simultaneously

Projected Sites

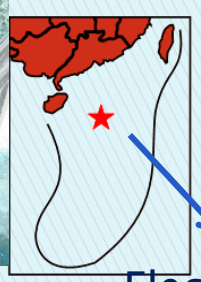




Electricity & Heating



Electricity & water



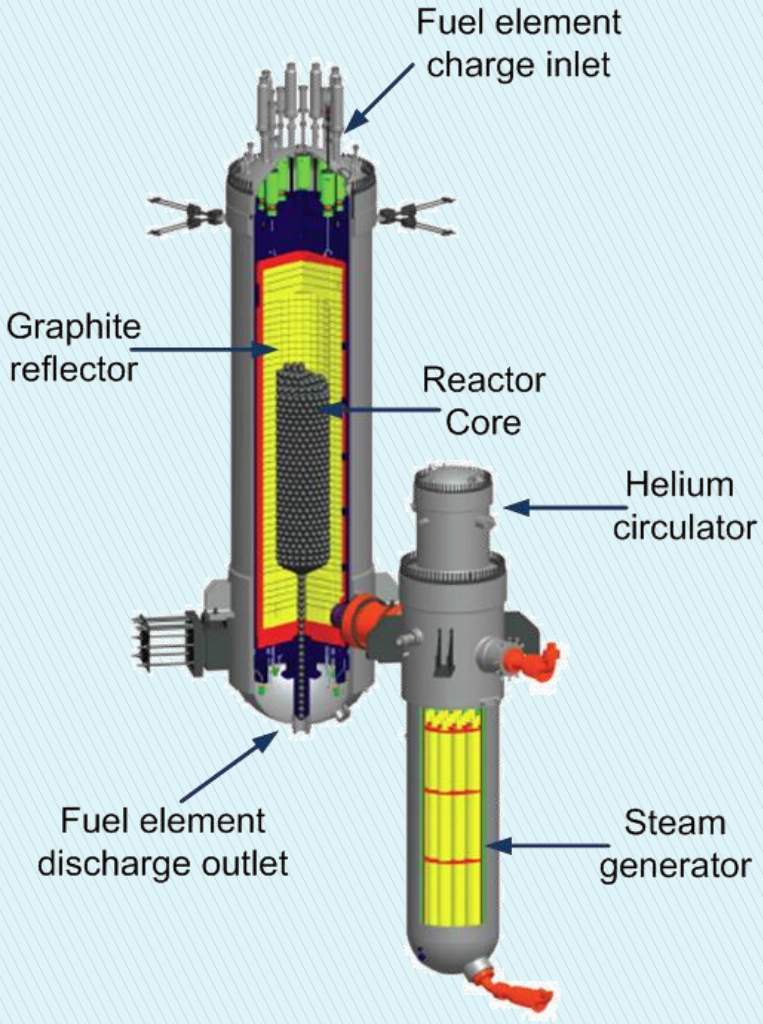
Electricity & water

Electricity & Steam

省级高新技术产业开发区——金沙园发展规划图

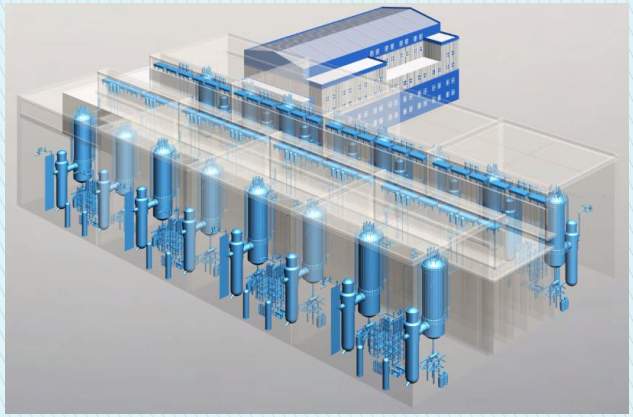
High Temperature Gas Cooled Reactor
-an effort towards Generation IV

High Temperature Gas Cooled Reactor –an effort towards Gen IV

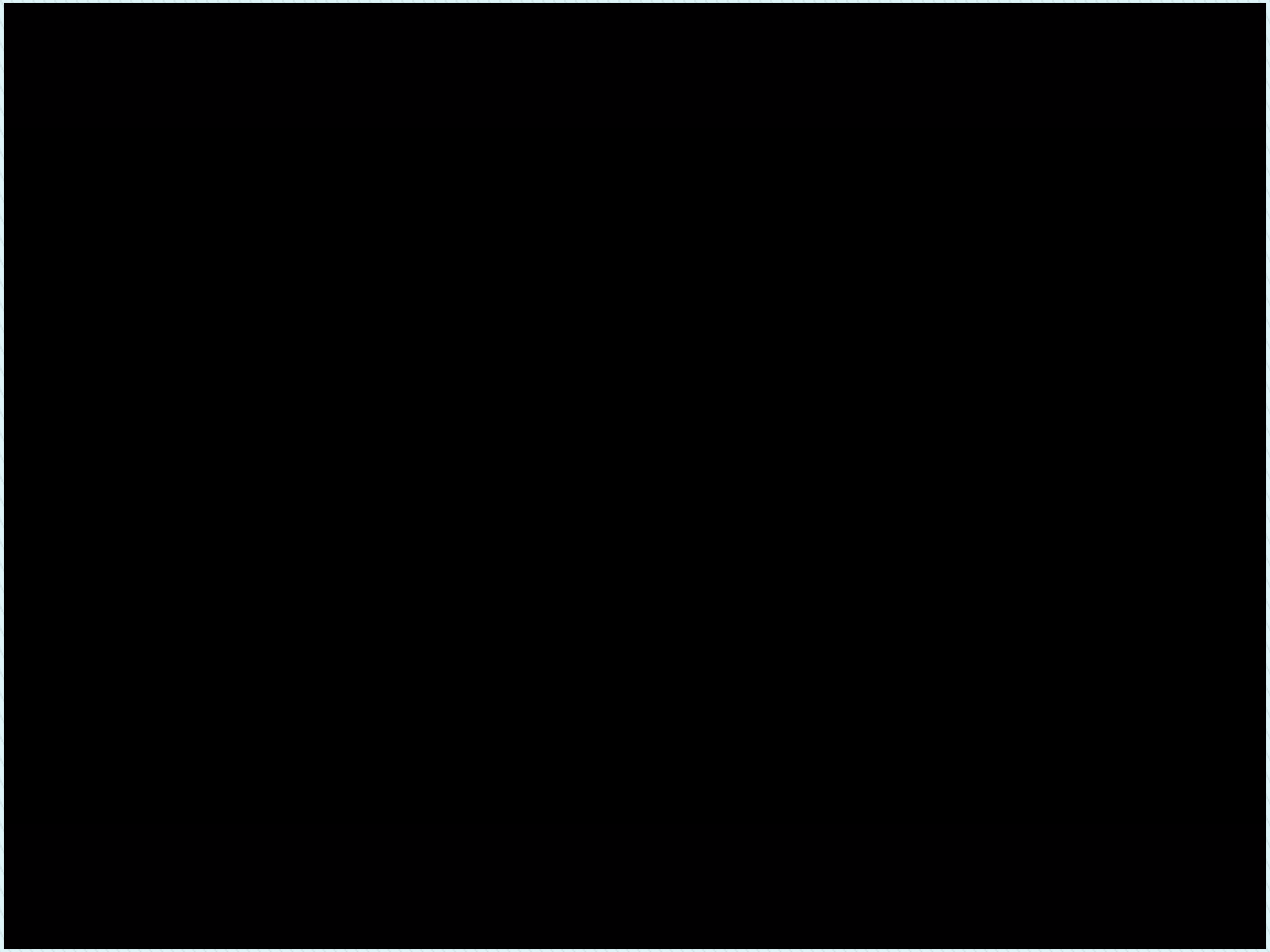


HTR-PM

- 100Mwe per module
- Inherent safety
- Self contained TRISO Fuel
- No off-site emergency area needed
- High efficiency
- No nuclear proliferation
- Continuously refueling
- Simplified system
- Modular design

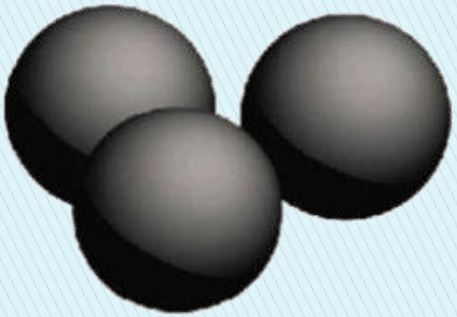


High Temperature Gas Cooled Reactor



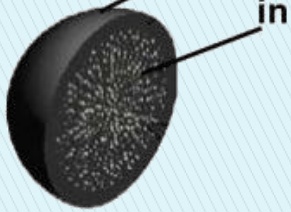
Retain of Radioactive Material

Fuel element design for PBMR

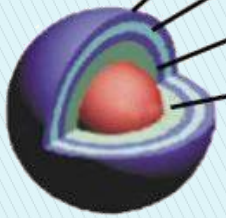


Diameter 60mm

Fuel sphere



Half section

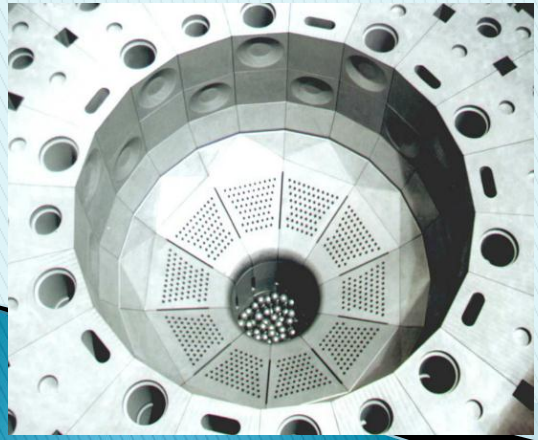


Diameter 0,92mm

Coated particle

Diameter 0,5mm
Uranium Dioxide

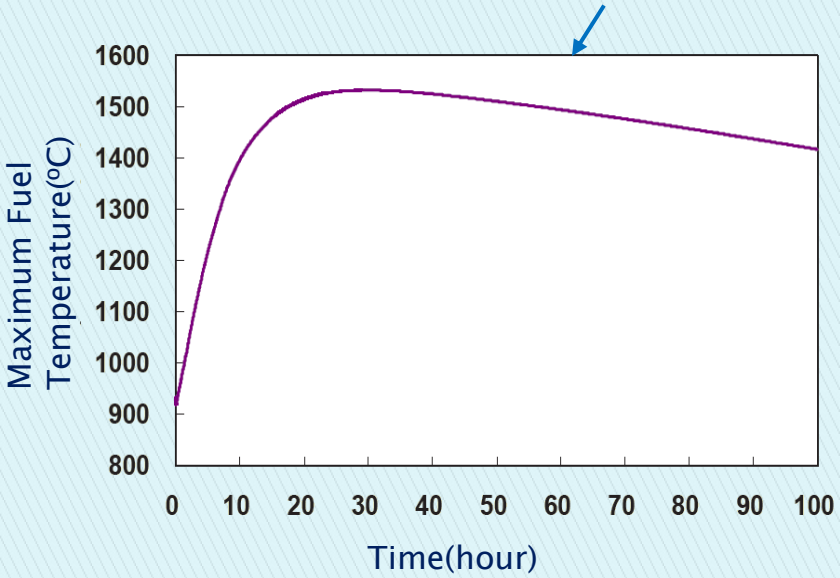
Fuel



Inherent Safety

In 2004, HTR-10 has been proved to be able to stay within designed fuel element temperature when the coolant(helium) is removed, an extreme case of LOCA.

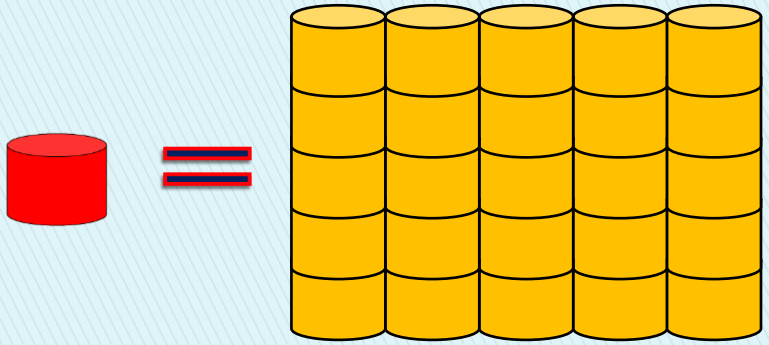
Fuel temperature limit



Negative reactivity to temperature

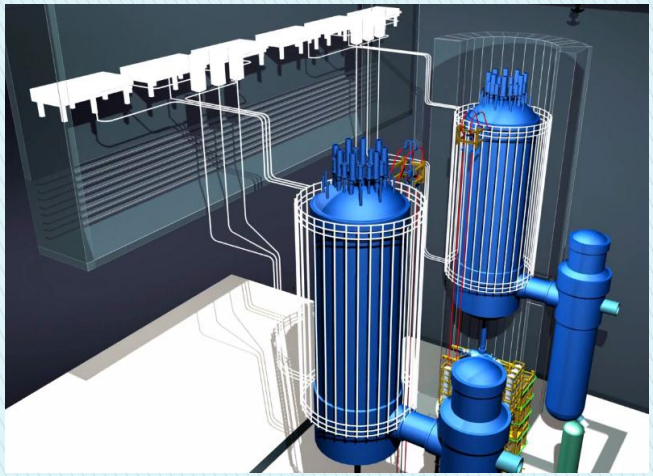
LWR
100MW/m^3

HTGR
3MW/m^3



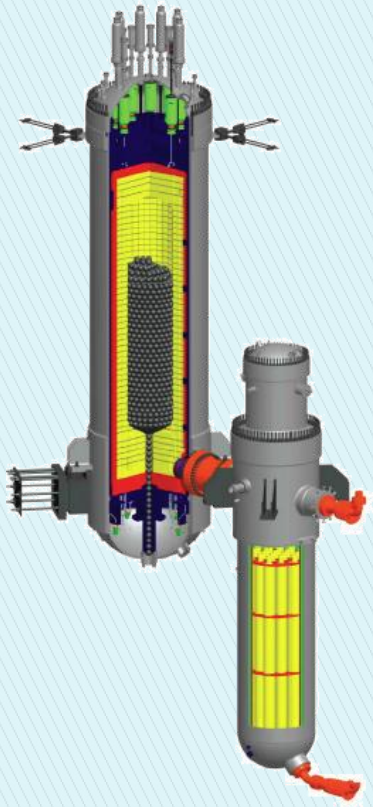
Low power density

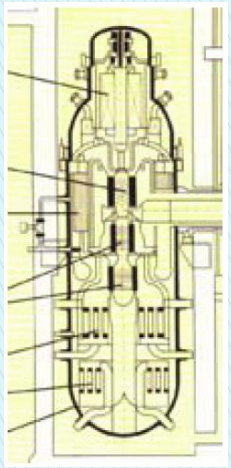
In addition to the role of moderator, graphite also serve as a huge heat capacitor in HTGR



Heat radiation and cooling walls

A developing technology

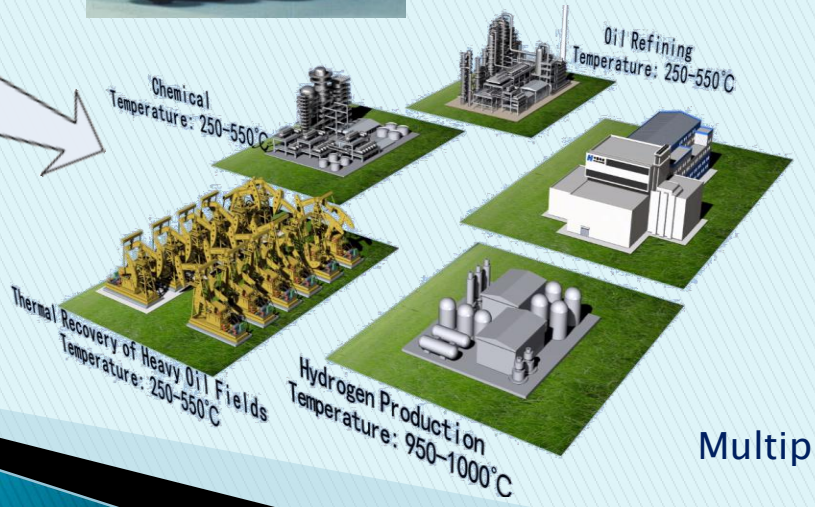




Higher Efficiency

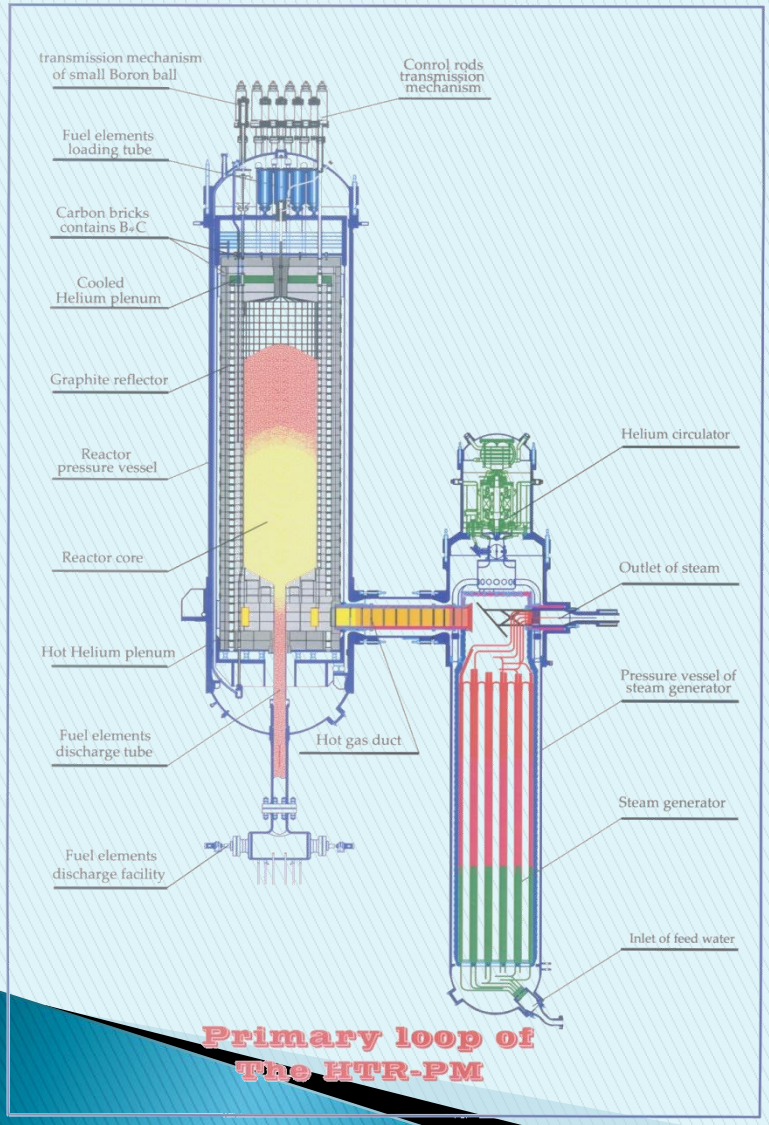
Helium circulator with electromagnetic bearing and helium turbine

Fuel post-process



Multiple Purpose

Technical Specification



The generation cost is yet to be competitive comparing to large reactors

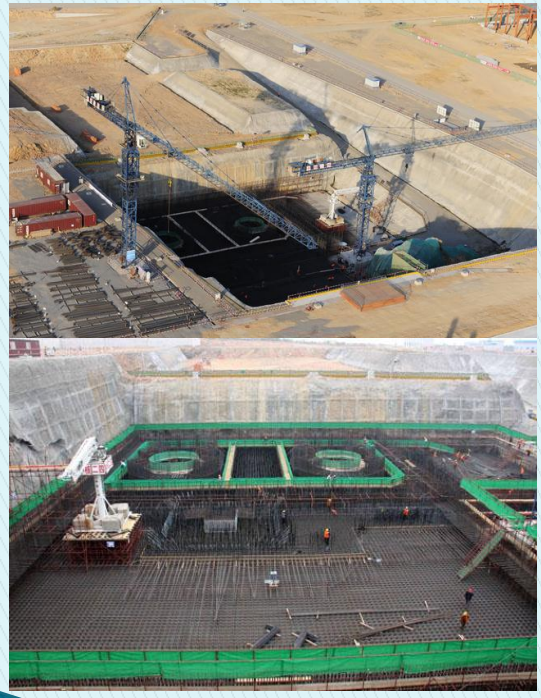
Thermal power	500 Mw
Electric power	200 Mw
Modules	2
Core diameter	3 meters
Core height	11 meters
Helium pressure	7Mpa
Core exit temperature	750ºC
Core enter temperature	250ºC
Main steam temperature	566ºC
Steam pressure	13.25Mpa

Recent Progress

2003 — HTR-10 Full power

2009 — HTR-PM ready for FCD

2011 — Approved by government



Construction Site

Reactor vessel forgings

Steam generator forgings

Summary

- The need to reduce coal consumption is more urgent than ever
- SMR could be an excellent substitution for coal in many situations in China
- Despite of the achievement, a "lift off" is unlikely until the design is proven and regulation for SMR is perfected.

"China will……continue effectively develop nuclear power on the basis that safety is ensured."

Prime Minister Wen Jiabao
27- 09-2011

Thank you !